Metallurgical & Chemical Engineering

Volume XIII, Number 9 September 1, 1915 McGraw Publishing Co., Inc.

Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XIII | NEW YORK, SEPTEMBER 1, 1915 | No. 9

PUBLISHED SEMI-MONTHLY ON THE FIRST AND FIFTEENTH OF EACH MONTH BY THE

McGRAW PUBLISHING COMPANY, INC.

JAMES H. MCGRAW, President.
A. E. CLIFFORD, Secretary. JOHN T. DEMOTT, Treasurer.

239 West 39th Street, New York.

TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.

ROCKY MOUNTAIN OFFICE........421 Boston Bldg., Denver, Colo.
PACIFIC COAST OFFICE......502 Rialto Bldg., San Francisco, Cal.
CHICAGO OFFICE..........................Old Colony Building
CLEVELAND OFFICE........................Leader News Building
PHILADELPHIA OFFICE................Real Estate Trust Building
LONDON OFFICE..............Hastings House, Norfolk St., Strand

E. F. ROEBER, PH.D., Editor.
H. C. PARMELEE, Western Editor.

J. M. MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for September 1, 1915

From now on "Metallurgical and Chemical Engineering" will be published semimonthly, on the first and fifteenth of each month. The change from a monthly to a semimonthly has been forced upon this journal by the rapid industrial development of the fundamental idea of which it has been the journalistic exponent—that for the future development of engineering a sufficiently broad and comprehensive basis can only be obtained, if the chemical viewpoint is considered of equal importance for the evolution of our industries as the mechanical and physical viewpoint has been in the past in its application to mechanical, mining and electrical engineering. While the general public has been slow in recognizing the enormous importance of this fundamental idea, the creative power of this idea has been perfectly obvious to those who look below the surface of things. Manifestations of this idea in the economic life of this country are the evolution of the electrochemical industries, the emancipation of the metallurgist from the mining engineer, the dissociation of the chemical engineer from the chemist, and the quiet, steady, healthy, irrepressible growth of industrial undertakings in many phases of metallurgical engineering and chemical engineering—all achievements of hardly more than the last decade. The whole evolution has now accumulated such a momentum that its development is rapid and its influence grows daily broader. That the calamity of the European war has opened the eyes of the American public to the dependence of all our industries on chemistry and metallurgy, is purely incidental. The evolution of metallurgy and of chemical engineering as new engineering professions independent of mining and chemistry has been going on peacefully and logically these last ten years and has left its marks on the whole industrial development. And the American chemical and metallurgical industries are firmly established, rapidly growing realities. To those responsible for the conduct of this journal this evolution has been a subject of intense gratification, but also a source of embarrassment in the endeavor to do justice to the situation, until it has now become evident that the needs of the profession and of the industry which this journal endeavors to serve can no longer be taken care of properly in a monthly publication.

With the change to a semimonthly we wish to attain two objects—first, to cover more intensely and more completely the well defined field of this journal, and second, to do it more promptly, to give "news value" to the technical news we print. The change to a semimonthly means no change in policy, no fundamentally new viewpoint, but it shall mean more intense cultivation and greater promptness such as may be expected

from a live technical newspaper, but is impossible of fulfillment in a monthly. We believe that the service which the metallurgical and chemical engineering field—the profession and the industry—have a right to expect from the representative journal in the field, can be rendered properly in a semimonthly, and in trying to render it we are sure of the support and good-will of our readers which we have so fully enjoyed in the past.

To me personally, the growth of this journal from small beginnings in 1902 has been a constant source of pleasure. It seems eminently fitting that the publishing company which publishes the "Electrical World," the "Engineering Record" and the "Electric Railway Journal" has been instrumental in giving to the glorious new professions of chemical and metallurgical engineers their technical newspaper. I pledge my hearty support to "Metallurgical and Chemical Engineering" in its endeavors to work more strenuously than ever toward the realization of its ideals, and on its entrance into the semimonthly field I bid it God-speed.

James H. McGraw.

The Present Importance of Metallurgy

Not in years has the spirit of optimism been so prevalent in the western mining industry as at the present time. The unprecedented prices for metals and the prospect that those prices will be maintained have operated to loosen the purse strings of that part of the investing public that knows the hazards as well as the profits of mining. But the most significant feature of the revival is the fact that those who are anxious to engage in mining are no longer frightened at the prospect of encountering a difficult metallurgical problem. The rapid progress in metallurgy in the past few years has inspired confidence and has aided wonderfully in the extension of the mining industry. As expressed by one engineer: "If I can only find the mine, I have little doubt of being able to develop a suitable treatment process."

If the past few years have been lean in mining, they most assuredly have been fat in metallurgical research and development. Our time has been spent to good advantage. And now that our opportunity is at hand we are able to make full use of the knowledge that we have been at such pains to gather. In the absence of the discovery of new mining districts operators are looking for neglected opportunities in the dumps and mines of abandoned districts, confident that the metallurgical difficulties and handicaps of the past can be readily overcome.

A good example of this kind of revival, based wholly on the development of modern metallurgy, was chronicled in our last issue. To bring life and activity to a district that has been abandoned for a score of years is an achievement of which the metallurgical industry may well be proud. Doubtless there are other such opportunities. They may lack the spectacular features of those projects that are conducted on a huge scale, but they afford a chance to put into practice the special knowledge that has been developing for several years.

Flexibility in Finished Steel Production

The steel industry has been giving a remarkable exhibition of its flexibility as to the production of different descriptions of finished steel. The engineers have been calling for specialty mills, and it really would seem from a scrutiny of the majority of large steel plants that specialization has been carried very far, yet despite the great change that has occurred in the distribution of demand among the various finished steel products the steel mills appear to be fully equal to the emergency. They appear to be able to operate at capacity and yet to furnish the buying trade with respective proportions of bars, plates, sheets, skelp and what-not that are demanded.

A part of the flexibility that is exhibited is due to the fact that from one product to another one mill begins before another has altogether left off. Thus the regular sheet mill can roll fairly heavy gages, while the jobbing mill can encroach both upon the sheet mill and the light plate mill. Each mill performs best on its specialty, but is not altogether limited to it. In merchant or bar mills the different sizes of mills yield their best service in a relatively narrow range of sizes, but are not confined to those sizes. Almost since there have been rail mills and billet mills there have been built "interchangeable" rail and billet mills, which could change from the one product to another merely by changing rolls. In the past few months still greater flexibility has been secured in certain rail mills, by changing rolls and adapting them to the production of large steel rounds, for which there has been a very heavy demand. The demand for ordinary merchant steel bars has been abnormally large, but thus relieved the bar mills are able to keep up with their orders fairly well.

Apart from the considerations just mentioned, the apparent flexibility of steel-finishing departments is maintained in large part by there being a very considerable excess in steel finishing over steel-making capacity. Probably at no time in the history of the steel industry, as now constituted, has it been possible to find sufficient steel to operate all finishing departments at 90 per cent of their real capacity. As new plants have been erected they have usually started with insufficient finishing capacity, and have appeared in the market as sellers of billets or sheet bars, but it has been almost the invariable history for such plants to add finishing mills one after another, so as to have reserve finisihng capacity and be able to catch the market in its various twists. Local conditions determine largely whether or not this is a wise policy. There is some investment lying idle, or but partly employed, in a plant that is making steel at capacity but has an excess of finishing capacity, but if it were not thus aligned it would at times have idle steel-making capacity instead. In the case of the plant the United States Steel Corporation is completing at Duluth, strictly local conditions obtained, and this plant was laid out to give the finishing mills a wide latitude in the character of the product they could turn out, for the demand in the far Northwest is yet to be gaged, and the plant is built largely against the demand of the

future. Such flexibility, of course, is purchased at the expense of an increased cost per ton, but in a practically isolated plant the first thing to do is to arrange to fill such demand as develops.

Chemical Engineering

The announcement of Columbia University on the establishment of a separate department of chemical engineering, independent of the department of chemistry, is but another characteristic sign of the times. The only other American university where this experiment has been made before, is, we believe, Wisconsin. Yet it is a most natural and logical development when once the conception of chemical engineering, its function and scope, are fully understood. No one would now suggest that for the training of mechanical engineers and electrical engineers the department of physics is sufficient. Yet the analogy with chemical engineering is as perfect as analogies can be, and the really interesting feature of the Columbia announcement is that it is Columbia University which takes this step.

Another characteristic sign of the times is the emphasis laid on chemical engineering in the series of able papers at the recent annual meeting of the British Society of Chemical Industry, reported elsewhere in this issue. Particularly Dr. Beilby's paper will be found most interesting and suggestive in defining the chemical engineering viewpoint.

Steel Capacity and Demand

The prince and pauper industry, otherwise the steel-making industry, has passed through its period of depression and entered upon a period of prosperity. It is either a feast or a famine, a chill or a fever. There are reasons. Two of them are, first, that inasmuch as steel is employed rather than consumed, the quantity that is put into employment in any one year may vary within wide limits, and second, that inasmuch as stocks of steel are carried by buyers rather than by producers the market demand increases or decreases more greatly than the actual employment or consumption, as buyers increase or decrease their stocks.

A little reflection and study of the statistics will indicate that there is in existence in the United States fully 400,000,000 tons of iron and steel, all performing more or less useful service, and naturally the additions to the store from year to year are not uniform. In 1905, 1906 and 1907 there were very large additions, since by far the major portion of the steel made in those years could be traced directly to large employment operations, in bridges, buildings, rails, cars, locomotives, etc. The present demand, however, does not run so largely in that direction. There is, for example, a large demand for steel for war purposes, where the actual employment covers in some instances only a few seconds of time. The second of the two causes noted above for the steel industry being either prince or pauper is the more potent at this time. A large tonnage of steel is distributed by jobbers, while another very large tonnage is purchased from the mills by manufacturers of hardware, machinery, motor vehicles, agricultural implements, etc. These buyers, jobbers and manufacturing consumers carry such stocks of the various sizes and descriptions of steel as they consider adequate to the smooth conduct of their business. When the steel mills are slack of work they can make very prompt shipment against new specifications, not hesitating to change rolls, for instance, from day to day or even more frequently. When they can accumulate a tonnage ahead they arrange their rolling schedules to much better advantage, and thus almost overnight, in a trade revival, the buyer of steel who has hitherto been able to count upon shipment in two or three days may be confronted with a delivery promise of a month or longer. Promptly he increases his specifications, for to conduct his business satisfactorily he must carry much larger stocks than formerly. The steel trade is now in the condition just indicated.

The steel industry may have difficulty in attaining the stage of operating at capacity, and indeed for almost two years there has been more or less idle equipment, but once the capacity stage is reached the full operation lasts for quite a while. In the past seventeen years there have been five such periods of marked improvement, resulting in capacity operations, full employment being reached in 1899, 1902, 1905, 1909 and 1912. The shortest period of full employment was that in 1912-13, approximately a twelvemonth, while the longest was that centering in 1906, about three years. In the shorter periods the chief influence causing the demand upon the mills to exceed the average was the desire of buyers to replenish stocks. In the longest period the chief influence was an actual consumption quite above the normal.

Each time the iron and steel industry reaches a stage of full employment the production is found to be much in excess of the best rate previously attained, and naturally by the amount that capacity has increased the period of full employment is shortened. The condition at the present time is therefore distinctly peculiar in two respects—in that the present capacity is only slightly greater than that of two years ago, when the industry was fully employed, and in that there is not likely to be much disposition to increase capacity in the next year or two. There has been little increase in blast furnace capacity in the past two years, and while there has been considerable increase in open-hearth steel making capacity, it is very doubtful whether the real steel making capacity of the country has been increased by anything like a corresponding amount, when there is question as to there being adequate supplies of pig iron and scrap, and there is less call for Bessemer steel than formerly. As to new construction at this time, a labor shortage is in prospect, and from this and other causes construction is likely to be expensive, while on account of financial conditions during the war, and the prospective release of much steel-making capacity at the close of the war, steel manufacturers are likely to hesitate in the matter of making very large increases in their productive facilities. Thus the period of full employment of steel-making capacity may this time prove to be unusually long.

Readers' Views and Comments

Adjustment of the Direct Electric Lighting Current to Electro-Analysis

To the Editor of Metallurgical & Chemical Engineering:

SIR:—The broadening of the field of usefulness for electro-analysis in the metallurgical laboratory by the introduction of agitation of the electrolyte, and also by the application of the theory of graded potentials, has been of great worth to the chemist and to the manufacturer. However, the writer believes that sufficient stress has not, as yet, been put upon the substitution of accurate, clean-cut electrolytic determinations for older and considerably cruder methods. This especially applies to the average laboratory engaged in work on the metallurgy and chemistry of iron and steel.

In order to do what he can in furtherance of a broader application of electro-analysis as applied to routine work, the writer wishes to describe an arrangement of apparatus which has saved time, labor and expense, with a large gain in accuracy and satisfaction.

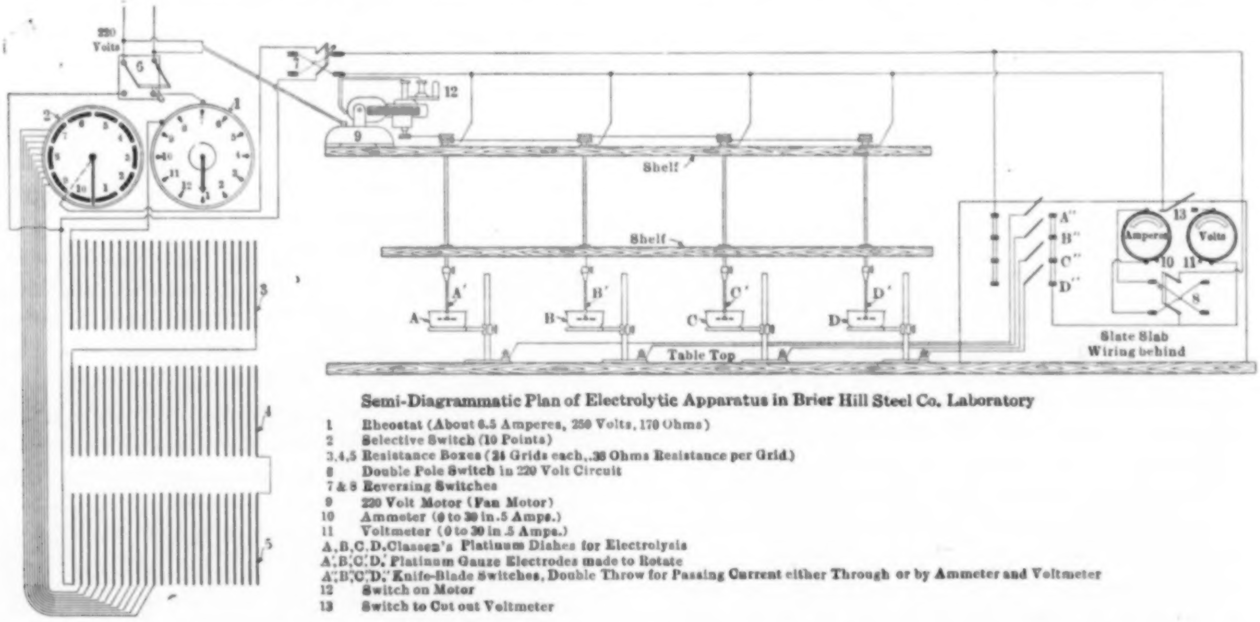
It was decided, when designing the electrolytic apparatus about to be described, to do away with the troublesome and expensive storage battery, utilizing instead the direct electric lighting current. At the same time it was decided to retain the advantage of simple and accurate voltage regulation possessed by the storage battery. It was not desired to use the familiar and inconveniently crude lampboard resistances, so the following was evolved.

The direct current, 220 volts in our case, is led through a suitable rheostat in series with three resistance boxes of the grid type; then by means of a selective switch suitable shunts are established, the voltage of these shunts being that of the drop in potential between the shunt connections. By manipulating the selective switch and rheostat in conjunction with each other, any voltage from 0.1 volt up to that desired may be reached, the current, measured in amperes, obeying Ohm's law according to $C = \frac{E}{R}$.

The accompanying sketch will explain the arrangement so that any electrician can easily install the apparatus. This sketch shows provision for four simultaneous determinations. This obviously may be changed to a lesser or greater number. For the 110-volt circuit, just one-half of the resistance shown in the sketch is necessary. For the 500-volt circuit, just twice this resistance must be used. The resistance boxes and rheostat, if not at hand, may be made if it is not desirable to purchase them. "Nichrome" wire for the resistance; fiber board for the rheostat and selective switch; the contact pieces may be made of large, heavy, copper rivets; the contact arms of spring bronze. The rivets should be spaced so that the contact arms in their travel always touch one or two contact points. This obviates arcing. There should be, for the 220-volt circuit, about 400 ft. of No. 18 "Nichrome" wire for the rheostat, and 70 ft. of the same kind of wire for forming the coil from which the potential drops are taken by means of the selective switch.

There should be twenty-four contact pieces on the rheostat and ten contact pieces on the selective switch, the leads from the rheostat being equally spaced along the 400 ft. of wire and in series with it. The leads from the 70-ft. coil to the selective switch are best adjusted by having the voltmeter and ammeter in circuit along with a pair of electrodes immersed in acidulated water. The current adjustment demanded by the class of work most handled may be easily and quickly obtained by increasing or decreasing the amount of resistance between successive shunts. The frames or boxes upon which the coils are to be wound are best made of "Transite" board. This may be worked with wood-cutting tools, and is resistant to heat as well as being a good non-conductor. The leads from the resistance coils to the rheostat and selective switch are of No. 12 well insulated copper wire.

The writer has used the outfit as sketched for the following determinations: Copper, tin, antimony (separation of tin and antimony), bismuth, nickel, manganese, iron, zinc and lead. The determination of lead in spelter was especially helpful, inasmuch as a great many determinations were required which, by the familiar



Semi-Diagrammatic Plan of Electrolytic Apparatus in Brier Hill Steel Co. Laboratory

1 Rheostat (About 6.5 Amperes, 250 Volts, 170 Ohms)
2 Selective Switch (10 Points)
3,4,5 Resistance Boxes (24 Grids each, .36 Ohms Resistance per Grid)
6 Double Pole Switch in 220 Volt Circuit
7 & 8 Reversing Switches
9 220 Volt Motor (Fan Motor)
10 Ammeter (0 to 30 in .5 Amps.)
11 Voltmeter (0 to 30 in .5 Amps.)
A, B, C, D, Classen's Platinum Dishes for Electrolysis
A', B', C', D', Platinum Gauze Electrodes made to Rotate
A'', B'', C'', D'', Knife-Blade Switches, Double Throw for Passing Current either Through or by Ammeter and Voltmeter
12 Switch on Motor
13 Switch to Cut out Voltmeter

lead sulphate method, were very tedious and not nearly so accurate as the electrolytic method. To make a lead determination on spelter requires 30 min., the lead peroxide resulting from the electrolysis being ignited gently and weighed as the red oxide.

With some additional wiring and a small change in the selective switch, the apparatus may be arranged so that two or more unlike determinations may be handled at the same time; that is, a determination requiring say 5 amp. at 5 volts may be carried out with a simultaneous determination requiring 2 amp at 3 volts, etc. This is accomplished by using one pair of switch arms at the selective switch for each electrolytic place required. Each pair of electrodes must have, of course, its own pair of wires corresponding to their respective switch arms. It will be readily understood that by simply setting these switch arms so as to "bite" off the requisite resistances the voltages and amperages desired may be secured. However, this is a modification that is only desirable for quite variable work.

To conclude, the writer wishes to strongly emphasize the value and importance of a broader application of electrolytic work in the iron and steel laboratory, and hopes that the foregoing description will be of help to others desiring to test out such methods.

Acknowledgment of helpful suggestions and criticisms is tendered Mr. H. E. Moyer, chief chemist for the Brier Hill Steel Company, and to Mr. Samuel Farrell of the same corporation.

EDMUND J. KAUFFMAN.

Brier Hill Steel Co., Youngstown, Ohio.

Platinum Boats for Carbon Determination by the Direct Combustion Method

To the Editor of Metallurgical & Chemical Engineering:

SIR:—There has been a great deal written in the past few years in regard to the direct determination of carbon in iron and steel. Many methods have been described for its estimation, and while they are all practically the same in principle, many different suggestions are made as to the best materials to be used for constructing a furnace and for boats in which the small drillings are carried. Various materials have been mentioned for this purpose such as porcelain, fused silica, alundum, vitrified clay and nickel, but rarely, if ever, is platinum mentioned, perhaps on account of it being so expensive.

There appeared in this magazine for June (page 347) an article describing a method for preparing boats made of 22-gage sheet nickel; each boat to cost a trifle less than 5 cents, and good for at least forty combustions. On this basis let us make a comparison between nickel and platinum.

The writer has used the same platinum boat for five years and five months, doing an average of fifteen combustions each day, twenty-six days each month, or in other words the boat has been used for 25,350 combustions to date. The boat weighed 19.6 grams when purchased and it weighs at the present time 19.1 grams, so that there was a loss of 0.53 gram. It was purchased when new for $1.13 per gram, therefore the loss in platinum has cost $0.60. The boat is in fairly good condition at the present time, and is good for many more determinations. At the present price of platinum it could be sold for more money than it cost.

At forty combustions for each boat it would have required 634 nickel boats to complete the same amount of work done by this one platinum boat, and at 5 cents each the nickel boats would have cost $31.70, besides the trouble and expense necessary in preparing them from the sheet metal.

Nickel boats are more expensive than platinum, and they are also objectional from the fact that they readily take up oxygen at high temperatures, causing a continual formation of the black oxide which peels off in the form of small scales. This, of course, is an annoyance to the operator. A platinum boat is always ready for use and it is not necessary to scour it with cleaning compounds or treat it with strong acids to keep it clean. The only attention necessary is to keep it in shape as a boat, and this will not be found difficult if a suitable form is kept on hand for this purpose.

Great care should be exercised in regard to the flow of oxygen passing through the combustion tube, as this is an essential factor in prolonging the life of a platinum boat. With a furnace temperature of 1900 deg. Fahr., and a rapid flow of oxygen the temperature at which the reaction actually takes place will probably reach 2500 deg. Fahr., and at this temperature the drillings will run together like so much mercury and fuse with the boat, indeed sometimes they will bubble high above the boat and fuse with the combustion tube. Many times this has occurred to the above-mentioned boat and it has been found best to cool the furnace. When the slag becomes brittle it can be easily broken from the tube and the boat removed. When a platinum boat is removed from the furnace under these conditions it will not resemble its original shape by any means. In fact, it is a fused mass of platinum and slag. However, with an instrument for crushing the slag, such as a pair of pliers and a steel form, the slag can be removed and the boat hammered into shape in a few minutes. The best results are obtained when the oxygen is so regulated that the drillings just fuse together, but not to the extent that they cannot be recognized as drillings. When the reaction takes place too rapidly, the iron is partly volatilized and if barium hydroxide is used the precipitate will be found contaminated with the reddish brown oxide of iron. The results will invariably be low. Probably some of the carbon escapes through the absorption apparatus as carbon monoxide.

White silica sand is used freely in the boat, since it costs practically nothing. The sand is heated to 2300 deg. Fahr., for some time before using, to free it of any small amount of carbon. This sand being white offers a good background for the drillings and is very desirable for this work.

What has been said in regard to the use of platinum boats is equally true in regard to the use of platinum as a heating element for the combustion tube. The writer has used the same furnace every day for eighteen months, while on the other hand a furnace constructed in the same manner, but using nichrome for the heating element, will not average three months' use, and at the end of this time it is necessary to renew the nichrome, while with platinum the same piece can be used several times.

H. F. SIEVER.

NEW BEDFORD, MASS.

Newspaper Chemistry of Platinum

To the Editor of Metallurgical & Chemical Engineering:

Sir:—The startling information contained in the following story, taken from the *Dowajiac Daily News*, is a beautiful example of "journalistic chemistry" and should be the means of furnishing some amusement to your readers:

"There is some valuable land down in Jefferson township. Recently a property owner on the line of the Mud Lake Extension drain sent to the State department at Lansing a sample of the excavation made when the drain was dug, and among other things the chemist found was platinum at the rate of 6 lb. per cubic foot of the formation.

"His primary object was to see how much lime the marl contained, and he was informed that the marl was over 90 per cent pure lime.

"Years ago, when platinum was worth $12 per lb., his land was a gold mine, although in those days cost of extracting this metal was correspondingly great, perhaps. With the facilities now in use for extracting, platinum has grown to be valued less than $1 per lb. Even at that price the land is pretty valuable."

Dowagiac, Mich. J. C. A.

The Western Metallurgical Field

Parcel Post Ruling to Affect Shipment of Concentrates

Since the parcel post was established, one of the most difficult problems confronting the Post Office Department has been the handling of tons of concentrates that have been shipped from isolated districts to smelting centers. Concentrates properly come within the classification of parcel post matter, and when put up in 50-lb. sacks have been entitled to the established rates. This method of shipment has been a convenience to producers operating at a distance from reduction works, and many of them have taken advantage of this method of transportation.

The Post Office Department has discovered, however, that the business is not profitable because the length of rural mail routes is frequently much greater than the parcel post zone radius as the crow flies. This often necessitates carrying concentrates a distance equivalent to two or three zone radii, and as a consequence the business is conducted at a loss. Hence a ruling has been made that where the mail route is 300 miles or more between points of shipment and delivery the regular first and second zone rates shall not apply, even though the route lies within those zones on the map, but that third zone rates shall be charged. This means, for example, that where the second-zone rate of 5 cents for the first pound and 1 cent for each additional pound has previously been in effect on some 300-mile routes, the third-zone rate of 6 cents for the first pound and 2 cents for each additional pound shall apply. This will increase the ordinary second-zone rate from $1.08 to $2.08 per 100 lb., or at the rate of $20 per ton. This is an increase that will force many operators to discontinue shipping by parcel post; the rural mail carrier may again use a two-wheel cart instead of a motor truck, and the government will be relieved from an unprofitable business.

Anaconda to Enter Zinc Field

Certain activities on the part of the Anaconda Copper Mining Company point to the possibility of that company becoming a factor in the zinc industry. Anaconda engineers have recently been examining property in the Neihart district, one of the zinc-mining districts of Montana, where silver-zinc ore has been produced, though with unsatisfactory results. In the Butte district also the Anaconda is reported to be investigating zinc properties, such as the Emma and Lexington, and it is reported that when the sale of the Alice is finally consummated the purchaser will be the Anaconda company.

With the acquisition of zinc properties, it is likely that Anaconda has also developed metallurgical methods to treat the ore, and some credence may be placed in the report that the company's metallurgists have been experimenting along the line of electrolysis. Electrolytic zinc has been in the public eye for some time, and has received quite as much attention as did electrolytic copper. The development of an economic hydrometallurgical method for zinc, with electrolysis as the final step, would be a tremendous advance in zinc metallurgy; in fact, it would prove revolutionary in an industry in which the basic methods have never undergone any material change. Were the report credited to any less energetic and capable an organization than Anaconda, it might not be worth a passing consideration, but the progressive character of Anaconda's program in copper metallurgy leads one to feel that new developments in zinc-ore treatment might easily emanate from that source.

American Graphite Manufactures

In view of an interest recently manifested in the domestic production of graphite and its manufactured articles, we give the following information: The production of natural graphite in the United States in 1913 was 4775 short tons. Imports amounted to 28,879 short tons. The principal reasons for the disparity in domestic production and imports are to be found in the superiority of the Ceylon product and its cheap production, and the difficulty in milling the domestic ores. Deposits in the United States are mainly flake graphite in schist. The separation is difficult, especially when the rock contains mica, which is frequently a constituent. Failure has attended so many undertakings in the production of graphite from domestic deposits that the work is in the hands of a few concerns which also manufacture the output into marketable forms.

Domestic graphite is not suitable for the manufacture of pencils, as it lacks that unctuous quality so necessary in producing an even grade of "lead." Crucibles, paints, lubricants and stove polishes are the manufactured forms to which the American graphite is most suited. The Santa Maria graphite mines in Sonora, Mexico, produce amorphous graphite containing 86 per cent graphitic carbon, which is shipped to Saginaw, Mich., and there prepared for use by the Raymond system of pulverizing and air-separation. American-made pencils, of quality said to be equal to that of German and Austrian manufacture, are now produced almost wholly from this Mexican graphite.

Silver and Base-Metal Prices

The steady decline in the price of silver is a matter of grave concern to producers of the white metal, particularly in view of the enhanced value of zinc, aluminium and potassium cyanide which are used in its production. Quicksilver also is used in large quantity at Cobalt, but as it is subject to but little loss in the process of amalgamation, its high price is not a matter of so much importance. In fact, the Buffalo company probably discovered a neat asset in the 41,850 lb. of mercury recovered from residues during the year ended April 30, 1915.

Tonopah and Cobalt are the great silver producing districts on the North American continent, and companies operating there have been forced to witness a steady decline in the value of their product while the cost of supplies has risen. The effect has been to cause operators to store silver bullion in New York and San Francisco until a more favorable market appears. But even this expedient has its unfavorable aspect, for by the time the market recovers to a normal condition the large stores of silver available will tend to hold prices down. Most of the companies concerned are well financed and can await a favorable time to dispose of their product, but smaller companies that have to realize promptly on their output are operating under most unfavorable conditions.

Potash in Utah

The Mineral Products Company, which is developing deposits of alunite at Marysvale, Utah, expects to have its milling plant in operation in September. Accord-

ing to General Manager James A. Lane, no attempt will be made at present to recover aluminium, which is a constituent of alunite, and potash only will be produced. The company has been constructing a tramway and mill, and will begin operations under favorable market conditions.

Flotation at Park City

We have recently commented on the fact that the older mining districts offer fertile fields for the application of the flotation process, particularly where concentrating mills of the customary type have been the only treatment plants in operation. A case in point is the Park City district, Utah, where gravity concentration of lead-zinc ores has long been practised. The Daly-Julge mill is to add the Callow pneumatic flotation process to its present equipment, and thereby effect a saving of fine mineral that has hitherto gone to waste. Another project in the same district is the construction of a mill to re-treat the old tailings of the Grasselli company's dry concentrating mill. The flotation process will be used here also, in addition to the usual methods of wet concentration. At Atkinson, near Park City, a new 250-ton mill has been erected for the treatment of old tailings, flotation playing a prominent part of the process.

Company Reports

Utah Copper Company's report for the second quarter of 1915 shows a production of 40,799,825 lb. of copper from 2,215,159 tons of ore containing 1.42 per cent copper. The extraction was 64.85 per cent, being below normal due to the presence of considerable carbonate mineral in the ore, and to the extra large tonnage handled. The tonnage treated was the largest for any quarter in the history of the company. The cost of copper, without crediting miscellaneous earnings, was 7.49 cents per pound. With other earnings credited, the cost is 6.57 cents. Total net profit from all operations was $4,412,299, from which a dividend was paid amounting to $1,624,490. Of the total quantity of ore milled, the Magna plant handled 59 per cent and the Arthur plant 41 per cent.

Ray Consolidated Copper Co. treated 679,004 tons of ore during the second quarter of 1915, producing 14,524,380 lb. copper. The average grade of the ore was 1.677 per cent copper. Milling costs totaled 44.53 cents per ton, as compared with 48.95 cents for the previous quarter. Coarse crushing cost 3.256 cents per ton. The average cost of copper, after allowing for smaller losses and applying dividends from the Ray & Gila Valley Railroad, was 9.122 cents per pound. Crediting miscellaneous income, the average cost would be 9.057 cents. The net operating profit was $1,367,736; dividend amounted to $547,035. Production for the quarter averaged nearly 1000 tons below what it should have been under normal conditions. Delay in resuming operations on a full tonnage basis, coupled with labor difficulties in June combined to cause a deficiency in production.

Chino Copper Company produced 18,455,502 pounds of copper during the second quarter of 1915. The mill treated 592,200 tons of ore containing an average of 2.38 per cent copper. The average daily tonnage was the highest in the history of the mill, reaching up to 7317 tons per day in June. Extraction was 65.34 per cent, as compared with 66.12 per cent in the previous quarter. The concentrates contained 22.11 per cent copper, as against 27.41 per cent for the first quarter. The ratio of concentration was 14.19:1. Cost of copper, allowing for smelter deductions and crediting miscellaneous income, was 6.10 cents per pound. Net profit from milling operations, $1,937,951; dividends paid, $652,455.

Nevada Consolidated Copper Company produced during the second quarter of the calendar year 15,106,920 lb. of copper, the June production being 5,124,480 lb. Ore milled amounted to 849,155 of Nevada Consolidated ore averaging 1.40 per cent copper. In addition to this there was also milled 17,541 tons of Giroux Consolidated ore. The cost of copper, after crediting miscellaneous income, was 8.93 cents per pound. Earnings for the quarter amounted to $1,364,094, from which dividends were paid amounting to $749,796.

The Non-Ferrous Metal Market

Since our last report the non-ferrous metal market has been comparatively quiet and without particular feature. Prices have steadily declined and business has been only moderate. While sales have been mainly for the domestic market, there is evidence that export business will again increase and it is not felt that the reaction will be marked or of long duration.

Copper.—Export business has suffered somewhat from the sale of Australian and Japanese copper in the European market, but resumption of foreign sales has already begun. Domestic business has been small and at reduced prices. The latest available quotations for electrolytic are 17.60@17.80 cents, New York.

Lead.—Due to a sharp reduction in price by the American Smelting & Refining Company this market has lost its optimistic tone that it showed in July. Competitors have still further reduced the price, so that lead is now quoted at about 5 cents, New York, and 4.90@5 cents, St. Louis.

Tin.—This market has been without special feature. Prices have shown a declining tendency, and the metal is quoted at 35½ cents, New York.

Spelter.—The metal has been consistently weaker for several weeks and the volume of business is small. There seems to be an ample supply for both immediate and future demands. Some metal has been offered for resale by buyers who overbought their requirements. The St. Louis quotation is about 14.50@15 cents.

Other Metals.—Aluminum continues at a fairly high level with fair demand. No. 1 ingots at New York are quoted at 31@33 cents per pound. Prices for antimony are largely nominal, ordinary brands bringing from 35 to 37½ cents, and special brands 48 to 50 cents. Business in quicksilver is only fair, with prices at $92@94, New York, for flasks of 75 lb. The San Francisco market is quiet with prices about the same as at New York.

The Iron and Steel Market

August has shown a further improvement in the steel situation. Although practically 100 per cent of the open-hearth capacity and about 90 per cent of the Bessemer steel-making capacity has been engaged, steel has been described as scarce and prices demanded for billets and sheet bars support such a view. Mill deliveries have lengthened out so that against new specifications filed for plates and shapes the large mills do not promise shipment in less than four to six weeks, while in the case of bars deliveries are still slower. Steel prices have been advancing.

On the surface at least the steel market presents an appearance of great strength, and in most quarters the prediction is made that the trade is definitely promised a long period of full prosperity. When the market situation is analyzed, however, it becomes clear that its strength is due chiefly to export demand, and that mainly for war purposes. This demand has had both a direct and an indirect effect in filling the steel mills

with business. Indirectly it has affected domestic buying by stimulating the price advancing tendency and by causing buyers to fear they may not be able to secure desired deliveries. In the last report it was noted that when mill deliveries begin to fall behind buyers are moved to increase their stocks, and while it was then noted that such an extra demand was being experienced it may be stated that the buying during August was still more of that character.

The government figures for June show exports of iron and steel totalling 355,829 gross tons, against 263,649 tons in May, and an average of 137,000 tons a month during the first seven months of 1914 preceding the outbreak of the war. Excluding pig iron, scrap, castings, etc., the June exports represented about 320,000 gross tons of rolled steel. Indirect exports, including machinery, arms, ammunition, motor cars, etc., may have involved 80,000 tons in addition, making 400,000 tons for the month. The country's capacity, measured as rolled steel is probably about 2,400,000 gross tons monthly, with average weather conditions and after all departments have been in operation long enough to have reached normal efficiency. The June production was probably in the neighborhood of 1,800,000 tons, so that steel export, direct and indirect, appears to have represented about 22 per cent of the output. Exports have been steadily increasing since June in various directions. Large shipments of rails are to be made to Russia, purchases to date having amounted to 250,000 or 300,000 tons, while a large number of cars and locomotives has been bought by France and Russia, and there have been increases in many items that figured in the June exports. It is quite possible that in September direct and indirect exports may represent as much as 600,000 tons of rolled steel, but as moderate weather arrives and the mills through continued operation reach their proper gait it will be possible to produce more steel, probably the 2,400,000 tons per month already estimated, so that allowing for a gain of one-half in exports over what is suggested by the latest government statistics, the exports would represent only 25 per cent of capacity, indicating that in some quarters the importance of the present export trade, from a tonnage standpoint, is being over-estimated. There is little danger, however, of the influence upon the market being overrated, however, because, as indicated, the export business has had an important sentimental influence in helping the advance in prices and encouraging buyers to specify freely on their contracts.

Without admitting these influences it would be impossible to find in industrial conditions in the United States occasion for the steel industry to operate at its capacity. There is no important branch of domestic consumption in which business is active or in which the tonnage actually consumed is at previous record rates, whereas the steel industry has a larger capacity than ever. A few illustrations may be cited. The railroads have bought rails scarcely more freely this year than in 1914, but the production of rails last year was less than 2,000,000 tons, or only one-half the record production, made so long ago as in 1906. The last time the steel industry reached a rate of full employment was at the middle of 1912, and in the eight months preceding there has been 135,000 freight cars ordered. Freight car buying this time has been active only in the three months, May, June and July, orders in those months aggregating about 55,000 cars. Prior to May there was no buying to speak of, and there has been none of any consequence in August. The reports of the Bridge Builders' and Structural Society, covering fabricated steel contracts let throughout the country, show an average in lettings during the first six months of this year representing only 54 per cent of the capacity, while in the single month of July the contracts amounted to 86 per cent. Oil development is practically at a standstill, and has been for a year, while in a good year the "oil country goods" branch of the pipe industry involves nearly a million tons. In the sheet branch there is nearly normal demand for blue annealed and black sheets, but not one-third the normal demand for galvanized sheets.

Admittedly the steel trade finds itself in a prosperous condition, but obviously the condition is not referable to anything like normal full domestic consumptive demand, while even the export demand does not appear to fill the gap. As the country grows more prosperous the domestic consumption may, and probably will, increase. Perhaps the final test will come with October, normally a month of very large outputs, as the plant facilities work well. If the market finds itself strong at the end of October, with firm prices and no surplus of steel, the industry may be regarded as assured a period of prosperity of considerable length.

Pig Iron

The advance in pig iron prices, which became perceptible in the fore part of July and reached more important proportions in the second half, became very marked in August. Averaging all important descriptions of pig iron, the July advance amounted to about 35 cents a ton and the August advance to about 90 cents, a total of $1.25 for the two months. Prior to July the pig iron market had merely shown minor fluctuations.

The advance in pig iron has not rested upon as large a volume of sales as has usually occurred in the case of price advances of similar extent. The conditions were exceptional. There is a much wider range in pig iron costs at the merchant furnaces than there is at the furnaces of the steel works, one important factor being that some of the merchant furnaces have ore mines of their own while others must pay the market price, and an interest having ore mines and blast furnaces may be content to show an apparent loss to the blast furnace operation if the ore is charged to it at the market price. Last winter the furnaces in operation were confined almost entirely to those with ore supplies of their own, and even they were operating at no considerable profit. Pig iron prices remained low for so long that the furnaces were tempted to sell pig iron far ahead. At the beginning of July the furnaces found themselves almost entirely sold up for the second half of the year, while consumers were equally well covered, on the basis of the rate at which they had been consuming iron. A slight increase in their requirements caused additional buying, while the furnace position was that the operating furnaces were already well sold up and the idle furnaces were unable to sell and enter the producing ranks, their costs being well above the market. Accordingly, prices rose rather sharply on relatively light buying. To justify blowing in, a furnace must be able first to sell a considerable tonnage of pig iron, assuming prices to be satisfactory, and the market has hardly been broad enough to permit this. The market stands quotable as follows: No. 2 foundry, delivered Philadelphia, $15 to $15.25; f.o.b. furnace, Buffalo, $14 to $14.50; delivered Cleveland, $14.50; f.o.b. furnace, Chicago, $13.50 to $14; f.o.b. Birmingham, $11 to $11.50; at valley furnaces, 95 cents higher delivered Pittsburgh: No. 2 foundry, $14.25 to $14.50; gray forge, $14 to $14.25; malleable, $14.25 to $14.50; basic, $14.25 to $14.50; Bessemer, $15.50. These quotations are for relatively early delivery, and quotations for the first quarter or half of next year are usually on a higher basis.

Steel

The large consumers of billets and sheet bars are well covered by long term contracts. On some of these prices are adjusted monthly or quarterly, and have been increasing slightly. On a few contracts, particularly for sheet bars with tin plate mills, there is usually one price for the entire calendar year. The demand that passes through the open market is thus very small compared with the tonnage that changes hands, and in periods of relative scarcity the market is sensitive and not very clearly defined. Some of the producers are refusing to quote, having but small tonnages to spare, after filling contracts, and feeling safe in holding the steel for still higher prices. The middle interests have some steel but are naturally reserved in selling. As nearly as can be quoted the market stands at about $23.50 to $24 for billets and $24 to $24.50 for sheet bars at maker's mill. Bessemer steel might possibly be had for less while it might be difficult to buy open-hearth at these figures. Rods are $26 to $27, Pittsburgh.

Finished Steel

Finished steel products have, generally speaking, shown an advancing tendency. In bars, plates and shapes the new buying has been light, but specifications against contracts have been so heavy that the mills have felt strong enough to advance asking prices. On Aug. 16 the steel corporation subsidiaries announced an advance of $1 a ton in bars, plates and shapes, to 1.35c.; Pittsburgh and the other large interests are working up to this basis. There remain small plate mills willing to sell plates at 1.25c.

Current quotations, f.o.b. Pittsburgh, unless otherwise noted:

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.25c. to 1.35c.

Shapes, 1.30c. to 1.35c.

Steel bars and bands, 1.30c. to 1.35c., base; hoops, 1.35c. to 1.40c.

Iron bars, 1.25c., Pittsburgh; 1.40c. to 1.45c., Philadelphia; 1.25c. Chicago.

Sheets, blue annealed, 10-gage, 1.40c.; black, 28-gage, 1.85c. to 1.90c.; galvanized, 28-gage, 3.60c. to 3.75c.; painted corrugated, 2.00c. to 2.05c.; galvanized corrugated, 3.65c. to 3.80c.

Tin plate, $3.10 to $3.20 for 100-lb. coke.

Steel pipe, ¾ to 3-in., black, 79 per cent off list; galvanized, 63½ per cent off list.

Steel boiler tubes (less than carloads), 72 per cent off list.

Structural rivets, 1.50c.; boiler rivets, 1.60c.

Railroad spikes, 1.45c., Pittsburgh; 1.60c., Chicago.

Imports of Potash Salts.—The following table from **Commerce Reports** shows the quantity and value of imports of potash salts into the United States during the month of May and for the five months ending May, 1914, and 1915. The items are grouped to show the salts used chiefly as fertilizers and other potash salts. The unit of weight is the long ton.

Transvaal Gold Production.—The number of mines reporting to the Transvaal Chamber of Mines in April, 1915, was sixty-three. The total quantity of ore milled during that period was 2,341,595 tons. There were 9907 stamps in operation, with an average duty of 9.35 tons per 24 hr. Tube-mills in commission numbered 316. The yield for the month was 744,080 fine ounces gold, or 6.22 dwt. per ton.

Repairing Coke-Ovens by the Cement-Gun Process.—The Cement-Gun Company, Inc., 30 Church Street, New York City, describes in its Bulletin 101 the application of the cement-gun process for permanently repairing coke ovens. This method is interesting as it permits the repairs to be made while the oven is in service, thus doing away with the troublesome effects of cooling and reheating. The "gun process" is the same in principle as has proved so successful in other fields of cement repair work in recent years. The material used in the gun is the usual silica cement which is used in joints in the construction of the walls. This consists of siliceous material such as ground silica rock and ground batts in varying proportions from 100 per cent of the one to 100 per cent of the other mixed with 15 per cent to 20 per cent of fireclay. The finished cement generally running from 85 to 80 per cent silica. The material being deposited in the form of a spray and under high pressure penetrates deeply into the cracks, thus insuring a perfect seal.

Oil Pipe Line.—The first four sections, comprising about 47 miles of the oil pipe line for the Valley Pipe Line Company, a subsidiary of the Shell Royal Dutch Company, which was designed and is being built by Sanderson & Porter, was placed in successful operation on May 15th. This line is 170 miles long, extends from the Coalinga oil fields to a tidewater terminal near Martinez in San Francisco Bay, and will have a carrying capacity of 25,000 barrels per day. In order to comply with the wishes of the Shell Company for prompt completion, the constructing engineers, Messrs. Sanderson & Porter, have pushed this work through in what is believed to be record time. The storage capacity of the pumping stations now in operation on this first section of the line amounts to 225,000 barrels, which is thus made immediately available for the storage of surplus production.

New Zinc Smelting Plants.—Within the past few weeks a number of old and abandoned zinc smelting plants have been put into commission, and new furnaces have been added to existing plants. The U. S. Steel Corporation is making good progress on its new zinc and acid plant at Donora, Pa. The U. S. Smelting, Refining & Mining Co. has purchased old plants at Iola, La Harpe and Altoona, Kan., giving the company an aggregate smelting capacity of 8000 retorts. The Grasselli Chemical Co. is adding two blocks of furnaces at Meadowbrook. Two blocks are being built in connection with the east plant at Pittsburgh, Kan., two at the Sand Springs works, one at Chanute and one at Bruce. An old plant at Nevada, Mo., is to be put in operation this month.

Articles	May				Five Months Ending May			
	1914		1915		1914		1915	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
Fertilizer salts:								
Kainit	11,960	$59,641	......	.....	239,362	$1,115,151	3,786	$31,553
Manure salts	19,047	203,632	197	$7,639	81,669	895,739	12,456	179,328
Sulphate of potash	2,162	94,788	33	2,204	21,313	907,635	8,806	405,631
Muriate of potash	17,952	619,397	28	3,845	105,759	3,606,445	56,135	2,336,098
Other potash salts:	Pounds		Pounds		Pounds		Pounds	
Carbonate of potash	1,621,787	48,548	769,047	24,947	9,867,075	282,758	8,396,034	261,234
Hydrate of potash	811,313	28,442	141,500	6,389	3,462,638	128,613	2,016,942	97,956
Nitrate of potash	475,724	15,170	......	.....	1,079,045	35,599	6,855	400
Cyanide of potash	1,236	16	......	.....	275,977	37,362	828,527	124,934
Other potash salts	512,383	44,519	67,203	7,698	2,704,391	241,075	2,064,260	202,570

Los Angeles Meeting of the American Institute of Chemical Engineers

The meeting held at Los Angeles from Aug. 16 to 18 by the American Institute of Chemical Engineers is the prelude to a long series of meetings to be held this fall on the Pacific Coast by the national chemical societies. It is to be followed shortly by another meeting of the same institute at San Francisco.

The Eastern members and friends of the institute—some thirty in number—had come to Los Angeles in several parties over the Santa Fé road. The main and official party was personally conducted by the secretary of the institute, Dr. J. C. Olsen, since the president of the institute, Dr. Rosengarten, was unfortunately prevented from participating in the trip on account of sickness in his family. Stops were made on the trip at Colorado Springs for excursions to Pike's Peak and Cripple Creek, and at the Grand Canyon in Arizona, while the exposition at San Diego, so delightfully characteristic of Southern Californian life and achievements, was enjoyed for a number of days.

The institute was entertained at Los Angeles with truly unbounded Californian hospitality by a local committee of the institute, consisting of Messrs. Edgar Baruch and D. B. W. Alexander, in conjunction with the Southern California Section of the American Chemical Society, of which Mr. Baruch and Mr. Henry L. Payne—both real live wires—are chairman and secretary respectively. For the many automobile trips which had been arranged for the entertainment of the visitors, cars were provided by Messrs. E. Baruch, N. M. Hill, R. B. Peters, H. J. Reese, M. P. Waite, Mark Walker and F. C. Winter. Among many others who did a great deal for the entertainment of the visitors, Messrs. W. L. Jordan, H. L. Potter, W. Hirschkind, H. L. Keller, C. H. McCharles, M. P. Spencer, and Mr. Thatcher of the Kieselguhr company should be specially mentioned. With so many active hosts it goes without saying that the visitors were almost overwhelmed with entertainment.

On Monday, Aug. 16, a 120-mile automobile trip was made; first to Redondo Beach, where the oil-fired power station of the Pacific Light & Power Company was inspected; it contains reciprocating sets of 15,000 kw. and turbine sets of 24,000 kw.; the cleanliness of an oil-fired boiler house was duly admired. The automobiles then proceeded to Long Beach; on the way the large-scale precipitation of salt from sea water with the aid of the sun's heat was seen. Lunch was taken at the Hotel Virginia in Long Beach.

In the afternoon the party proceeded to Huntington Beach, where the beet sugar factory was visited and the different chemical engineering processes were explained by the superintendent, Mr. Joseph Varra, and the chief chemist, Mr. A. C. Horn. The return trip to Los Angeles was made over Santa Ana and Orange through extensive walnut and fruit orchards.

The same evening a trip was made to Alhambra, where the mission play, concerned with early Southern California history, was seen. The whole of Tuesday was devoted to a trip to Santa Catalina Islands, while on Wednesday afternoon an automobile trip was made to Pasadena, and on Wednesday morning an automobile trip to the Fullerton oil fields, where the process of "squeezing" gasoline out of natural gas was shown. The technical details were fully explained by Mr. A. Yost, superintendent of the Brea Canyon Oil Company, and Mr. W. A. Culp, superintendent of the Pacific Gasoline Company. The informal lunch of watermelons and figs and the spectacle of a burning snowball (of frozen gasoline) will never be forgotten.

On the evening of Wednesday a joint meeting of the American Institute of Chemical Engineers and of the Southern California Section of the American Chemical Society was held at the University Club, and was preceded by an informal dinner. The attendance was about seventy. The occasion was graced by the presence of many ladies. Mr. Baruch presided. Introductory speeches were made by Dr. J. C. Olsen and Prof. J. M. Stillman of Leland Stanford University, vice-president of the American Institute of Chemical Engineers, who had specially come from Palo Alto to Los Angeles to welcome the institute to California.

Two very interesting papers were presented and elicited some extended discussion.

The first paper, by Mr. W. C. Hanna of the California Portland Cement Company at Riverside described the Fleming dust collecting system which is successfully used at that plant for collecting any dust and preventing damage to the surrounding orange groves. Briefly, the installation consists of normal rotary kilns using dry process and oil for fuel. The draft for the kilns and dryers is produced by fans sucking at the ends of separate flues. Instead of discharging the gases into the atmosphere, the same exhauster fan blows the dust and fumes into a large "dry dust settling chamber," where the velocity of the gases is reduced about 90 to 95 per cent, resulting in a large amount of dust being deposited.

The extremely fine dust which does not settle, and the gases, then go to the "wet washing chambers," where the gases are forced up and down several times while following a serpentine course through a system of seven baffle chambers, and the last of the original so-called cement dust is captured by sprays of water which are in each chamber.

These sprays of water also bring into solution much of the gases, lime and alkalies. In connection with both the dry and the wet chambers there are means provided for the removal of the captured dust to the cement kilns.

The second paper of the evening, by Dr. J. C. Olsen of New York City, described "a new electrolytic method of sewage disposal," in operation at Elmhurst, in New York City, for more than a year. The C. P. Landreth process is used.

The principal novel features, which distinguish it from other electrolytic processes for sewage disposal, are, first, that lime is used together with electrolytic treatment, and, second, that a much smaller quantity of electricity per gallon is used than in other processes. A very thorough system of agitation is also employed.

We reserve publication in full of these two very interesting papers for a future issue.

On Thursday, Aug. 19, the party left Los Angeles to proceed to San Francisco. But several stops were made on the way. The main party left the train at Oxnard, to visit, under the guidance of Mr. H. E. Zitkowski, general chemist of the American Beet Sugar Company, the Oxnard sugar factory, which is the largest beet sugar factory in the world.

The ladies of the party, under the guidance of Prof. Edward Bartow, proceeded to Santa Barbara to enjoy the beauties of the "California Riviera."

The writer left the train at Surf, and was royally entertained by Mr. Krieger on a visit to the immense and unique high-grade kieselguhr deposits at Polnoc and to the extended mills which have grown up in the last three years to supply kieselguhr or celite in various forms to the most diversified industries—a new proof that the old creative California pioneer spirit is to-day as live as ever.

Roasting and Leaching Concentrator Slimes Tailings*

BY LAWRENCE ADDICKS

Through the courtesy of Dr. James Douglas I am permitted to give a summary of some of the results obtained in leaching slimes tailings in a series of experiments conducted under my direction at Douglas, Ariz., during the past year.

While the test run for which the data are given deals with a particular case, much of the work is general in its application and may therefore be of interest.

This work was done upon the ores of the Burro Mountain Copper Company. A description of the geology of the district will be found in the paper by R. E. Somers published in the May, 1915, *Bulletin* of the Institute.

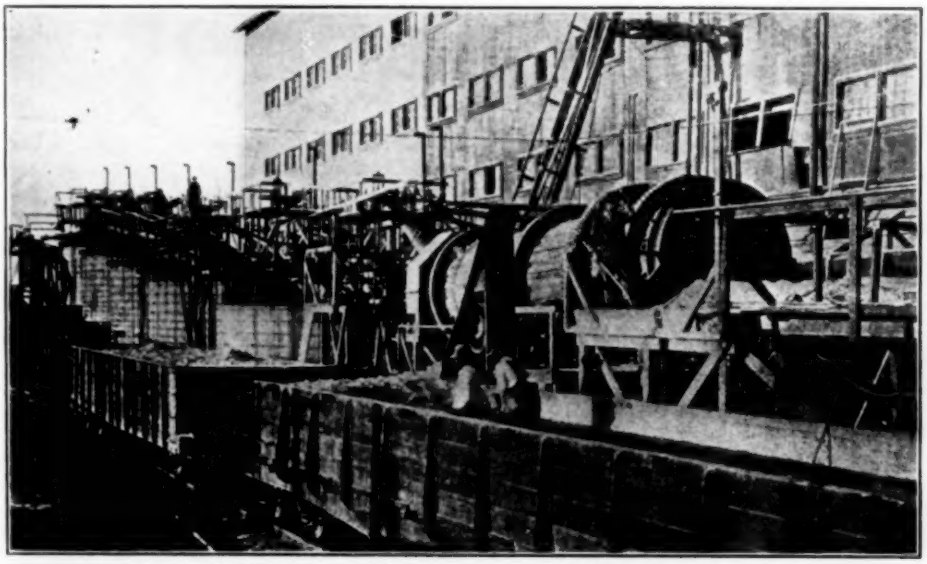


FIG. 1—GENERAL VIEW OF LEACHING PLANT

The mineral is pyrite and chalcocite very finely disseminated throughout the gangue and a characteristic of all the ores is the large amount of alumina present.

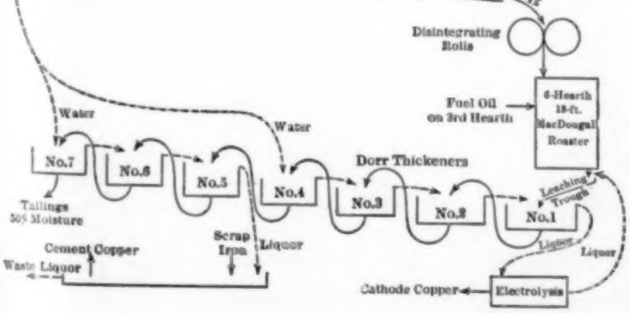


FIG. 2—FLOW-SHEET OF LEACHING PLANT

A representative analysis of the particular ore under consideration would be about as follows:

Cu, per cent	2.35	S, per cent	3.0
Ag, ounces per ton	0.05	CaO, per cent	0.5
Au	None	K_2O, per cent	4.0
Fe, per cent	1.5	SiO_2, per cent	70.0
Al_2O_3, per cent	13.0		

The leaching of the ore direct was early dismissed from consideration for the following reasons:

1. The ore would have to be quite finely crushed to liberate the mineral for leaching; concentrating after crushing would cost but a few cents a ton; and a higher total recovery would result from leaching tailings rather than ore.

2. Rough concentration would yield a suitable material for roasting to make sulphur dioxide or sulphuric acid in connection with the leaching scheme.

3. Such a program put the question of cost vs. recovery on a basis where flotation and discarding of tailings were directly comparable.

Concentrating experiments already available indicated that the tailings would consist of about 50 per cent of sands running about 0.3 per cent in copper, and therefore too low to justify retreatment, and 50 per cent of slimes running perhaps 1 per cent in copper, and it was on this latter material that the large-scale work was finally done.

At first flotation gave very unsatisfactory results, due primarily to the readiness with which the fine mineral particles became coated with a film of oxide upon exposure while concentrating, but later developments in this field overcame these difficulties and it became apparent just about the time the leaching plant was being started that the concentrator recovery was going to be so high that re-treatment of the tailings would not be justified. Nevertheless, for the sake of the data it was decided to carry through a representative run, the results of which are discussed below.

Fig. 1 is a view of the leaching plant, and the general scheme is shown in the flow sheet, Fig. 2. As the development of the electrolytic precipitation is really a subject apart from the leaching of the slimes, the results from this part of the work have been reserved for a separate paper. A part of the copper is shown recov-

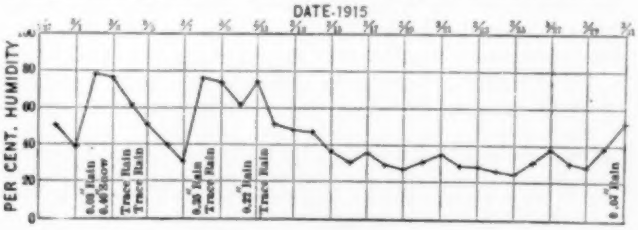


FIG. 3—MOISTURE IN AIR

ered as cement in order to give a means of holding the iron and alumina in the liquor to be electrolyzed down to the desired point. A high ratio of washing can be used in the thickeners delivering to the cementation launder; in the remaining thickeners the ratio is governed by the evaporation loss, as there is no other outlet for liquor.

The experiments will be taken up in detail under the headings of: (1) drying, (2) roasting, (3) leaching, and (4) washing.

Drying

As the slimes would be delivered from the concentrator in suspension as a thin pulp, it became necessary to consider carefully the question of drying.

*A paper to be presented at the San Francisco meeting of the American Institute of Mining Engineers, September, 1915.

Thickening experiments indicated that there was a critical degree of moisture of about 45 per cent, below which pumping the settled slimes resulted in further classification of the fine particles instead of delivering average pulp, so that thickening in a standard Dorr unit to 50 per cent of moisture was established as the first step.

As fuel is very expensive at the location in question and no waste heat can be counted on except that from the roaster gases, experiments were made with drying by exposure to the desert sun and winds. The heavy

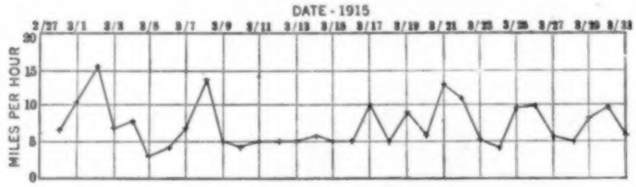


FIG. 4—WIND VELOCITY

pulp could well be poured into a shallow basin and the more or less dried slime reclaimed by some mechanical method for much less expense than an equivalent drying using artificial heat would cost. It was found that the pulp settled to about 30 per cent of moisture very readily when allowed to drain and that reasonable dry material could be obtained by a month's standing.

Figs. 3, 4, 5 and 6 give the measurements taken during the trial on three test beds, 10 ft. square, and respec-

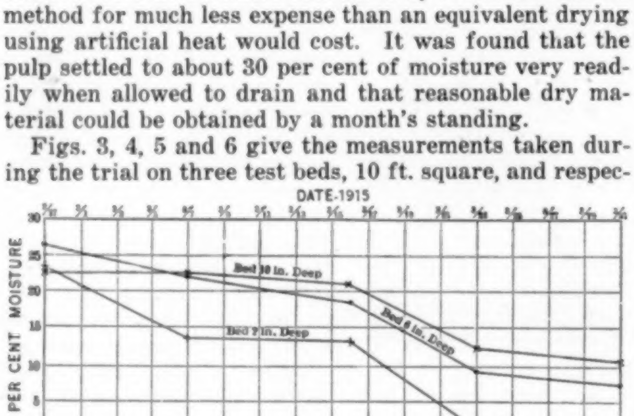


FIG. 5—MOISTURE IN SLIMES

tively 2, 6 and 10 in. deep, which were exposed to the atmosphere for about a month.

The climatic conditions are shown in Figs. 3, 4 and 6, and it will be noted that periods of both cold and wet weather were encountered during the first part of the run, much more favorable conditions following in the last two weeks. A bed only 2 in. deep would cost a good deal to reclaim, but the rate of drying, as shown in Fig. 5, was thought to indicate that a reasonably thick bed could be brought down to 10 per cent of moisture with-

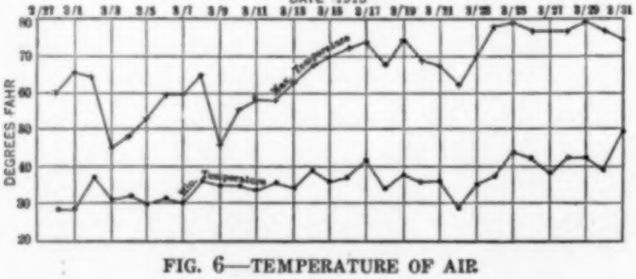


FIG. 6—TEMPERATURE OF AIR

out an excessive period of standing, and it seems probable that this will be the cheapest way to obtain this preliminary drying.

Up to this point the experiments were conducted on relatively small quantities of material, but starting with the following step—drying in the rotary kiln—large tonnages were handled. Instead of using atmospheric drying before feeding to the kiln, steam coils were buried in the cars of mushy slimes shipped to the experimental plant, bringing the moisture down to about 25 per cent, when it was shoveled directly to the drier.

This drier was one of the old Douglas roasters, 7 ft. in diameter and 31 ft. long. It was used as an ordinary unlined rotary kiln, with channel-iron spilling blades throughout the first two-thirds of its length, and cast-iron balls 3 in. in diameter feeding against a delivery screen made of sheet-iron plate with 1½-in. round holes. The idea was to dry and pulverize any caked nodules in the one apparatus. The outside was lagged with 1½-in. magnesia block, and heat was supplied by three oil burners at the delivery end. Two typical runs gave the following results:

Days run	23.0	12.0
Total tons dried	710.0	388.0
Tons per day	30.9	32.3
Per cent moisture entering	26.6	10.0
Per cent moisture leaving	1.1	2.0
Gallons fuel oil per day	404.0	154.0
Gallons fuel oil per ton dried	13.1	4.8

In general, it was concluded that about ½ gal. of fuel oil must be provided for each unit of moisture in the ore to be dried, so that 5 gal. would have to be charged against drying a 10 per cent product from the atmospheric drying beds, although this amount might be lowered in a properly designed drier. The capacity of the

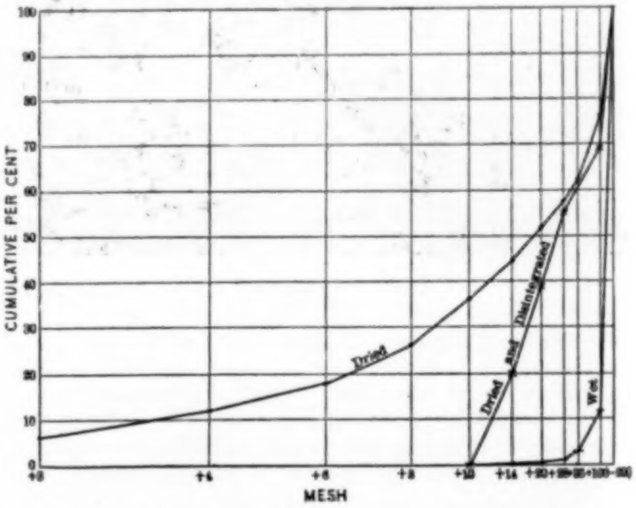


FIG. 7—CUMULATIVE SCREEN ANALYSIS OF SLIMES

drier was too low for the roaster used, and the pulverizing action of the iron balls inadequate, so the dried material was passed through a pair of disintegrating rolls, returning any oversize through a 10-mesh screen,

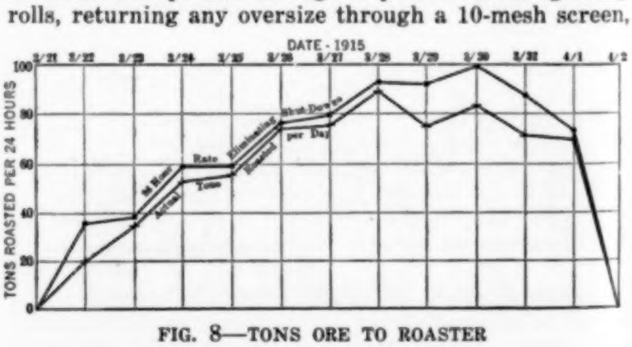


FIG. 8—TONS ORE TO ROASTER

and dried and disintegrated material was stored ahead of the roaster.

Fig. 7 shows cumulative screen analyses of the original wet slimes, the drier product, and the disintegrated material, made on the usual Tyler direct diagram. It must be remembered that the lumps formed in the kiln could be readily crushed between the thumb and forefinger, being merely caked clay. The danger was that

these lumps would be burned hard in the subsequent roasting.

The arrangement of the drier with skip feeding to roaster, and the row of Dorr thickeners can be readily seen in Fig. 1.

Roasting

The roasting was carried out in a standard six-hearth, 18-ft. MacDougall furnace with water-cooled arms, fuel oil being introduced on the third hearth. No change was made in the furnace for this work except to replace parts of the upper brickwork with firebrick. Fig. 8 shows the tonnage fed to the furnace daily during the particular run with which the remainder of this paper chiefly deals. When the arms began to be buried the

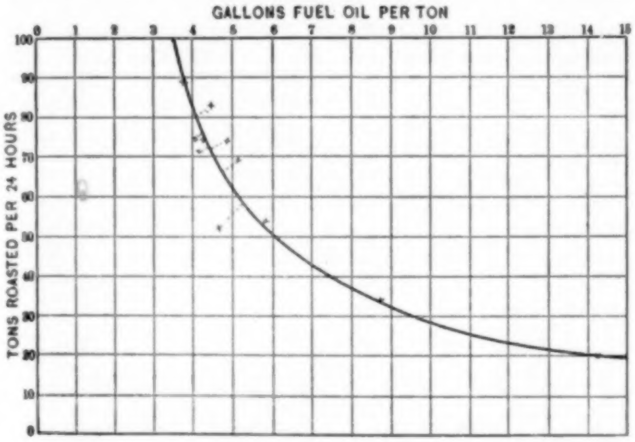


FIG. 9—ROASTER TONNAGE VS. FUEL-OIL CONSUMPTION

speed of rotation was increased from one revolution in 69 sec. to one in 60 sec. No trouble was experienced in the operation of the furnace.

Fig. 9 shows how the fuel-oil consumption was gradually cut down as the size of charge was increased. It is evident that 100 tons a day can be roasted with about 3.5 gal. of fuel oil per ton. The fuel oil burned was regulated so as to keep the maximum temperature on any hearth at about 950 deg. Fahr. Previous small-scale experiments had indicated that the proper roasting range lay between 900 deg. and 1100 deg. Fahr. Fig. 10 shows a log of the daily temperatures on the second, third, fourth and fifth hearths. It will be noted that the heat zone descended in the furnace as the tonnage

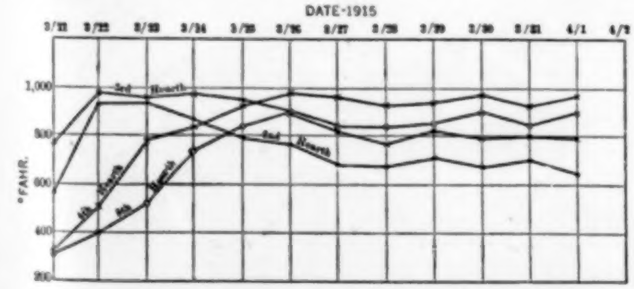


FIG. 10—ROASTER HEARTH TEMPERATURES

increased. This is shown diagrammatically in Fig. 11. At the same time the efficiency of the roast increased, as shown by Fig. 12. This is apparently due to the fact that at the higher rates, roasting temperatures were obtained on the fourth and fifth hearths, which were free from the more or less reducing atmosphere of the third and higher hearths due to the fuel oil.

Leaching

The hot calcines from the roaster were delivered through a spout casting made of Duriron into a rectangular trough about 30 ft. long, sloping 1¼ in. to the foot, which delivered directly into the first of the series of Dorr thickeners used for washing. This trough served three purposes: (1) that of leaching by agitation; (2) that of mechanically conveying the calcines from the roaster to the washing apparatus; and (3) that of absorbing the sensible heat of the calcines, thereby furnishing a warm liquor for electrolysis. A similar arrangement is described as doing excellent work in another field by Hofmann in his "Hydrometallurgy of Silver." A deep triangular trough was first constructed of common lumber. This was then lined with sheet lead

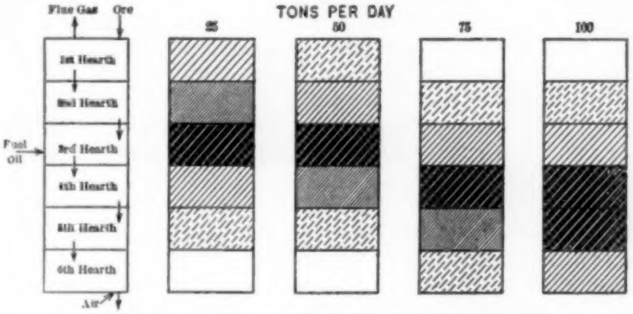


FIG. 11—ROASTER HEARTH TEMPERATURES

to make it liquor proof. Inside the lead lining, boards were loosely laid to prevent mechanical erosion of the lead by the calcines. A flat wooden cover was laid on top of the launder to keep down the steam and dust. This latter was not excessive, and would have been very slight had a more even delivery of calcines been made at the head of the sluice. The furnace arms alternated with light and heavy charges through the bottom drop hole and these were spread out over a reasonable time interval by placing an adjustable gate in the delivery spot, something on the plan of the classic hour glass. This worked fairly well, but it would have been better to have arranged some extra arms on the bottom hearth.

The copper content of the tailings at various points in their travel through the plant is shown in Fig. 13.

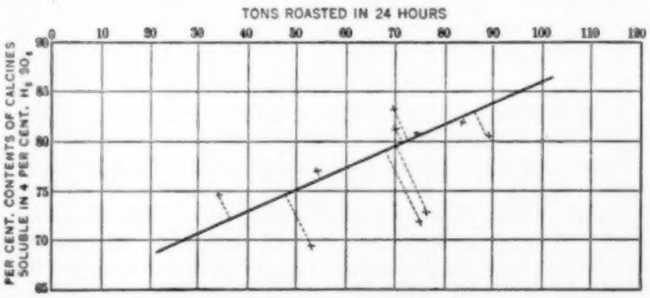


FIG. 12—VARIATION OF ROASTER EFFICIENCY WITH TONNAGE

The free sulphuric acid content of the liquor is shown in Fig. 14 and the effect of this strength of acid upon total extraction in Fig. 15.

The slimes as received assayed 0.84 per cent of copper. Fig. 15 shows that the calcines averaged about 0.74 per cent of copper, the grade falling as the furnace was gradually speeded up. This difference in assay was carefully investigated in the laboratory, and it seems very improbable that it was due to the formation of insoluble copper compounds during the roast, as three acids were used in the assay and various methods yielded but the merest traces of copper from the assay residue. The most probable explanation lies in the formation of particles of anhydrous copper sulphate during the roast, which blew over with the flue dust. No meas-

urements were made of the flue dust, as the furnace discharged into a common flue with other roasters treating concentrates.

The tails, as determined in the laboratory by heating samples of the calcines in 4 per cent sulphuric acid showed 0.2 per cent of copper, gradually dropping to 0.1 per cent as the furnace efficiency increased with the load. The actual final tails discharged from the last thickener ran about 0.1 per cent higher than the laboratory-leached calcines and laboratory tests showed this 0.1 per cent to be present as soluble copper. This same margin had been noted by Croasdale in his paper presented last year on his experiments at Ajo, and he there attributes it to the impossibility in practice of washing ore free from soluble salts. Fig. 15, however,

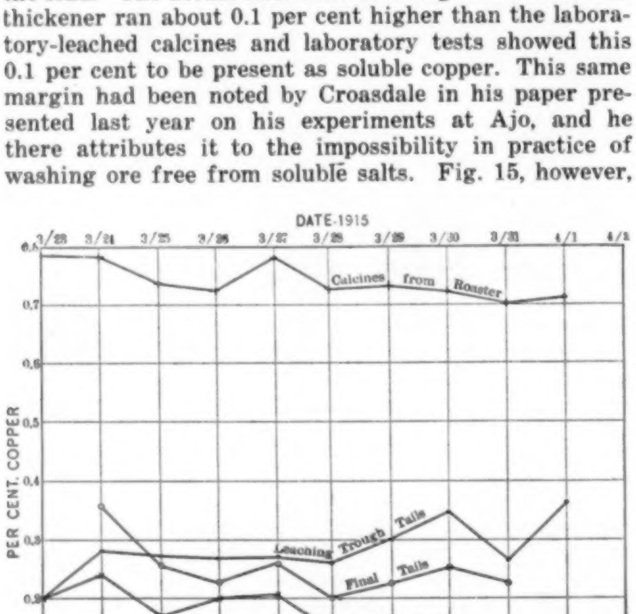


FIG. 13—COPPER CONTENT OF TAILINGS

seems to indicate that the difference in this case is largely due to the stronger acid liquor used in the laboratory tests.

Fig. 14 shows that the run was started with over 3 per cent of free sulphuric acid at the leaching trough and that this strength was allowed to exhaust itself gradually upon the entering ore as the run proceeded,

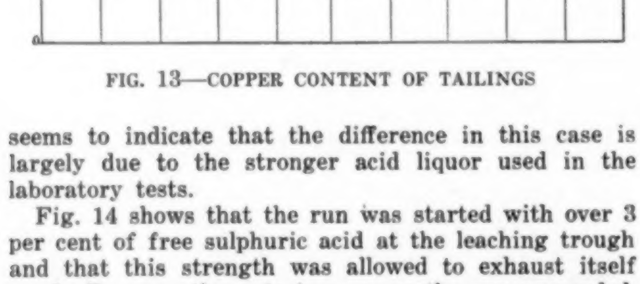


FIG. 14—ACID IN LIQUORS

the difference between final actual tails and laboratory tails increasing as the acid dropped. This same ratio is the basis of Fig. 14. It seems probable, therefore, that the strength of acid used will have to be considered in its bearing upon efficiency of extraction.

The leaching trough discharge ran but a few hundredths of a per cent higher in copper than the final tails after seven washings, showing that over 90 per cent of the leaching was done in the few seconds taken to travel down the trough. This high efficiency is due to the violent agitation when the hot calcines meet the relatively cool liquor, and to the fact that each particle of solid meets a fresh entering drop of liquor at the head of the trough, obtaining the full efficiency of the acid strength. An actual over-all extraction in practice somewhere in the seventies seems assured from these experiments.

Washing

The separation of the dissolved values from the exhausted slimes was one of the main problems presented. Any method of percolation was out of the question owing to the extremely fine state of subdivision of the material. The acid liquors employed, similarly ruled

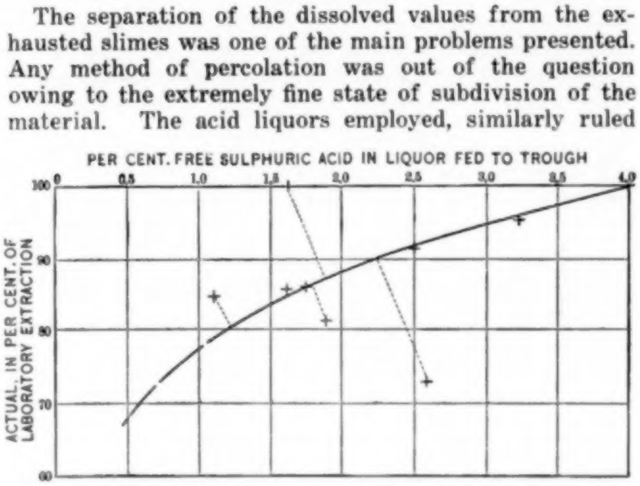


FIG. 15—FREE ACID IN LIQUOR VS. EFFICIENCY OF EXTRACTION

out many of the mechanical filters. It was finally decided to try out continuous counter-current decantation with Dorr thickeners of the acid-proof type of construction, some experience with which had been gained at the installation at the Butte-Duluth Mining Co.'s plant. Two 30 by 10 ft. and five 24 x 10 ft. tanks with suitable mechanisms and wood-stave pipes and fittings for 4-in. air lifts were therefore ordered and connected after erection in accordance with the flow sheet shown in Fig. 2.

The acid proofing of these mechanisms consisted of the substitution of wood for iron in the under-liquor parts. In turn, this called for some changes in design, two arms being used in place of four and the inclination

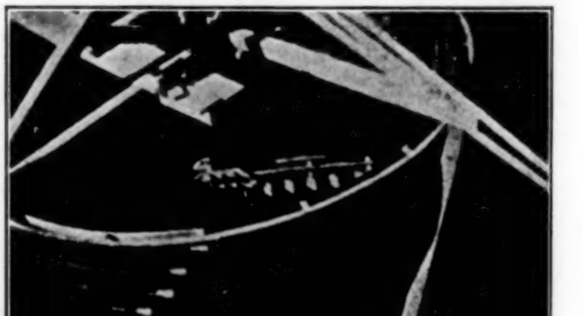


FIG. 16—THICKENER PADDLE

of the swept floor being lessened. Both these changes increased the digging load and the arms tended to ride rather than dig, extreme cases overstraining the unit. In spite of these difficulties the thickeners proved a practical apparatus. I believe, however, that the original metal construction properly protected by lead and equipped with Duriron rakes would be an improvement. An idea of the wooden construction can be obtained from Fig. 16.

The main difficulty was with the air lifts, and I am satisfied that these are not practical for the particular case. It must be remembered that it was desired to make an underflow of 50 per cent solids and that in the first thickeners many small lumps of slime had to be handled. When an air lift was gradually throttled until the desired thickness was obtained it no longer acted as a pump but more like a cannon, and a small capacity was obtained, finally resulting in one of two undesirable climaxes. Either a few small lumps settled out in the horizontal pipe under the tank, due to the slow flow, thereby choking it, or the lift would run thin for a moment followed by a rush as the normal pumping action was restored, stirring up the settled slimes and requiring constant attention for the next half hour in order to get the desired thickness of underflow. Also, the scouring action on the wood elbow at the point where the air was introduced was excessive, pipes sometimes wearing through in 24 hr.

Simple spigot discharge into a launder with some mechanical means of elevating was not promising, again due to obstructions making the flow of such a thick pulp very hard to regulate. Finally upon Mr. Dorr's suggestion two change were made: (1) a diaphragm pump was tried, and (2) the remaining air lifts were arranged to return a part of the underflow to the same tank, thereby increasing the solids moved and keeping the rate of flow in the horizontal feed pipe above the critical speed at which lumps settled out.

The diaphragm pump was an entire success. In the first place, the delivery depends almost entirely upon the stroke and speed and is not influenced by a momentary change in thickness as in the case of the air lift. Then the suction has the entire pressure of the atmosphere at its command and this is exerted whenever an obstruction is encountered. In fact, an ore sack and a pair of gloves were pumped up, to the surprise of the operator. It is astonishing how many things find their way into a system of this kind. A watch and fob and a brace and bit were among the articles added to our museum. Finally, the solids are moved steadily along and the scouring action is reduced to a degree which seems to make the use of wood pipe and fittings entirely practical. The pump was an ordinary 4-in. Gould contractor's pump with cast-iron body. The metal parts could readily be made of Duriron or other acid-resisting material.

During the run the temperature of the liquor in the first thickener gradually rose from 56 deg. Fahr. at the start until 100 deg. Fahr. was reached on the sixth day, at which point it was maintained by the sensible heat of the entering calcines. It was found possible to settle as high as 125 tons of solids in 24 hr. in one of the 30-ft. tanks. The overflow by actual test showed but 3 lb. of solids to the ton of liquor.

The liquors during the run accumulated sulphates corresponding to 10.0 lb. copper, 4.3 lb. iron, and 16.2 alumina per ton of slimes leached. The actual acid consumed was 49.0 lb. The acid equivalent of the corresponding metallic oxides is 70.5 lb., showing the presence of considerable sulphates in the calcines. A laboratory test on the calcines, using 4 per cent acid, showed a consumption of 68.9 lb. and a similar test on the product of a small-scale roast 69.1 lb. acid per ton. It appears, therefore, that less acid will be used in practice than in laboratory tests. Unfortunately, the run was not sufficiently prolonged to determine whether the proportion of impurities dissolved decreased as the liquors became more concentrated.

The **Arizona Copper Co.** produced 1758 tons of copper in **May, 1915.**

Metastability of Metals

BY A. VOSMAER

From more than one point of view it is important to recognize that metals are not always as stable substances as they appear to be. Professor E. Cohen of the Van't Hoff Laboratory, Utrecht, Holland, has carried out a large number of experiments bearing on the subject of metastability of metals and is continuing that work so that we may hope to have this difficult problem fully elucidated. It will be interesting and useful to the readers of this paper to be posted on the subject of allotropy of metals, since many a mystery in the world of metals has ceased to be such when the question of molecular transformation was considered.

The transformations of metalloids, such as carbon, phosphorus, sulphur from one modification into another are familiar to most people, but not so the transformations of metals which, by the way, are usually much less marked.

The man who, in a cold winter, buys a lot of block tin to store it away, runs the risk of finding a mass of grey powder after some time, instead of the solid white blocks. In fact, this did occur in Europe in the winter of 1858 and gave rise to the rather difficult question, whether or not tin in the white and in the grey state is one and the same substance. From a chemical standpoint it certainly is, but from a physical standpoint it certainly is not.

In fact, since we now have to admit that iron in the magnetized and the same in the nonmagnetized condition cannot be called one and the same substance, the problem of defining substances becomes a more and more difficult task for the scientist and it has also a practical importance in the industry. For it should be borne in mind that scientific research work can be of great benefit to the practical man, since the theory of metals and alloys not only explains mysteries and faults, but it also prevents mistakes and may even cure them.

The Van't Hoff Laboratory, through its head, Professor Cohen, has undertaken to study the question of metastability of metals and from the results published in the Royal Academy of Science of Amsterdam, we have prepared the following abstracts which give the gist of the results.

Allotropy of Bismuth[1]

Dilatometric research showed a sudden change in volume at a temperature of about 75 deg. C., when the alpha bismuth, stable at temperatures below 75 deg. C. changes into the beta bismuth, stable at temperatures above 75 deg. C. The alpha bismuth has a specific gravity of 9.732, the beta form 9.712. This is a considerable difference; it confirms the results of the dilatometric measurements which showed that the change from alpha to beta is accompanied by an increase in volume.

If we bear in mind that the beta bismuth differs in properties from the alpha modification and also that these molecular rearrangements take considerable time at temperatures lower than the transformation temperature proper, it is clear that as a rule commercial bismuth will always consist of a mixture of both modifications tending to reach equilibrium.

This explains why the physical constants of bismuth are as yet very far from being constant. Since the beta bismuth is a better electrical conductor than alpha bismuth, the specific conductivity of any sample of bismuth is bound to vary according to the ratio of alpha to beta bismuth in the sample.

Although the transition point is well defined at 75 deg. C., this does not mean that bismuth at a lower tem-

[1]Communication of June, 1913.

perature does not contain any beta metal. On the contrary, as a rule all bismuth will always contain some beta, as this form can very well exist in metastable condition.

On the other hand, it is noteworthy that the alpha bismuth may very well exist in metastable condition at temperatures above the transition point, even at temperatures as high as 150 deg. C.

In 1899 Perrot published his experience that the thermo electric potential of cast bismuth changes after some time without any apparent cause. Now we know from Cohen's investigation that this strange behavior of bismuth is not strange at all. Perrot's bismuth evidently contained some beta bismuth which slowly but surely turned to the stable alpha bismuth condition.

Determinations of the specific gravity, the melting point, the Hall effect, etc., have to be revised. All properties of bismuth hitherto determined except the atomic weight, must of necessity be corrected because not until 1913 was it known that all bismuth experimented upon may have consisted of a mixture—an undefined mixture—of alpha and beta bismuth.

We should remember the big difference between metals or alloys in the fluid state and in the solid state. It may very well be that in the fluid state all of the metal will be in the beta condition. On cooling down not all of the beta bismuth can find time to be converted to alpha bismuth and the beta condition is kept to a considerable extent in that form.

From a technical standpoint the change of specific gravity can be made use of. Every one familiar with castings knows the trouble caused by shrinkage; now bismuth and bismuth alloys possess the valuable property to expand on solidification, this, of course, gives rise to very sharp castings. It may be added that many of the fine Chinese metal castings of small objects for ornamental use contain bismuth. Unfortunately said change in volume—slight expansion on cooling—as observed by practical men in casting, cannot be explained by the allotropic change from beta to alpha bismuth at 75 deg. because it occurs at a much higher temperature and in a reverse sense.

It may be that there still is a third modification, gamma, of smaller specific volume than the beta and a second transition point a little below the melting point, but reports on bismuth do not mention this supposed third modification.

Allotropy of Antimony[2]

There have been four different forms of antimony known for some years, but the correlation of these has not yet been established.

Cohen investigated in how far commercial antimony, also known as metallic antimony, is to be considered as a metastable system and he came to the conclusion that it is metastable.

The four allotropic modifications of antimony are the ordinary or metallic, the black, the yellow and the explosive. The latter three are all metastable at ordinary temperatures.

Cohen's determinations of density led him to say that antimony after chilling, is in a form which changes at 100 deg. C., with a measurable velocity into a mass of different density. Probably about 96 deg. C. is the transition temperature.

The conclusion of this preliminary work is that antimony, as it is known in the familiar form, is a metastable system which consists of more than two allotropic forms. This is important in view of the extended use of antimony for alloys in technical arts.

Metals and alloys are judged, tested and paid for according to their properties and qualities. In case of dispute between buyer and seller in regard to quality the greatest embarrassment arises when authorities do not agree upon figures. But this will be unavoidable if metals are no longer what we think or thought them to be—definite substances. If a metal is a system of undefined composition as regards its own allotropic modifications, then we need not wonder about the discrepancies in physical constants and it is of the highest importance that the metal trade takes notice of the difficulties which may become traps in establishing definite figures.

Allotropy of Potassium[3]

Potassium is a metal of only very small importance for industrial uses and probably never will play an important rôle, but it is of interest to know that this metal also is subject to allotropic modification. The metal potassium as it has hitherto been known is at ordinary temperatures a metastable system in consequence of the simultaneous presence of two forms, alpha and beta potassium.

Allotropy of Copper[4]

It may surprise many people to learn that also in the case of copper we have a metal containing both alpha and beta copper, the transformation temperature being between 69.2 deg. and 71.7 deg. C.

In this, as in all cases, the transformation velocity depends largely on the presence of an electrolyte or of powdered metal which act as catalyzers. Under normal conditions the change of beta into alpha copper is so slow that it escapes notice unless specially looked for.

Remembering the changes undergone by tin and by zinc it is to be expected that bronzes and brasses will be subject to change as well.

Chemical Principles of the Blast Furnace

BY J. E. JOHNSON, JR.

This is a subject on which a number of large volumes have been written, but none of them have succeeded in elucidating the subject in such a way as to coordinate the accepted theories and the facts of practice to a profoundly useful extent. At the same time honor must be done to the work of some for their investigations which helped to lay the foundation, although not precisely for the structure which they had in mind.

Sir I. Lothian Bell in particular found time in a busy and highly successful commercial life to prosecute extensive investigations, to ponder at great length, and to record accurately the results of his labors in two large volumes in which I believe it is admitted that the first reasonably successful attempt was made to write a heat equation of the blast furnace. Most unfortunately for him and his disciples there are not one but two heat equations of the blast furnace, and in endeavoring to square all the conditions with this one equation he was led into errors which went far to vitiate the value of his work. But as a pioneer in applying chemistry and quantitative heat values to the operations of the furnace he is deserving of his high place in the esteem of furnacemen.

Gruner also set forth in 1879 the ideal condition of working of a blast furnace which has been too little heeded and has even been attacked in recent years as not universally correct, but I think I shall be able to show that Gruner is right and that his critic, through not realizing all the conditions, has fallen into error.

The action of the blast furnace must be considered in

[2]Communicated Oct., 1914.

[3]Communicated Feb., 1915.

[4]Communicated Dec., 1913; May, 1914.

three different aspects which sometimes merge into one another, but nevertheless can best be considered separately at first, the chemical, the thermal and the mechanical; in which order we shall consider them.

The Different Regions of the Furnace

An outline of a typical modern blast furnace is seen in Fig. 1. The cylindrical straight portion at the bottom is called the hearth or crucible or sometimes the well because it serves to contain the liquid iron and slag. The divergent cone above this is called the bosh. The short cylindrical portion and the long convergent cone above this, surmounted by another cylinder has so far as known to me no name established by universal custom, and I have been accustomed to call it the shaft, since the furnace as a whole is a "shaft" furnace and it is obviously this portion which gives it that name.

The furnace is expected to be kept filled to the line

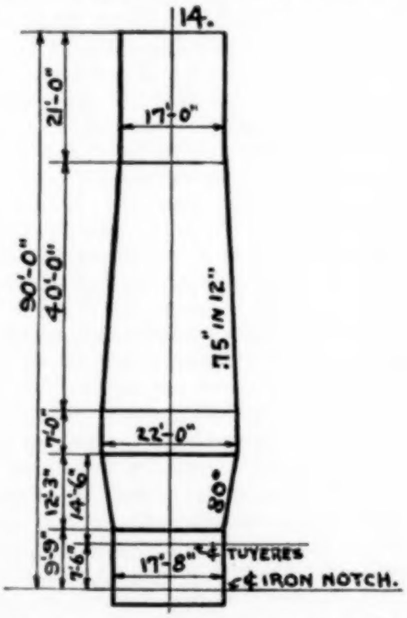


FIG. 1—LINES OF A MODERN BLAST FURNACE (SOUTH CHICAGO, NO. 4, 1914)

in the upper cylinder marked "stock line" and this is the diameter which is meant by the "stock-line diameter."

The height of furnaces, in the days of hand filling, was always measured from the hearth bottom to the top of the filling platform, but since the decline of hand filling the top platform is not quite such a definite and important level, having nothing to do with the level from which filling is done in mechanical charging, so it is better now to give the height to the bottom of the supporting collar on the hopper as that corresponds more nearly to the old top platform than any other equally definite point.

The size of furnaces is given by their height and diameter at the top of the bosh, very frequently the diameter of the hearth and stock line are added in the order given.

This terminology suffers from one defect. The word "hearth" denotes the level at which combustion takes place and connotes the laboratory of the apparatus in which the active work is done, but the region of the furnace which corresponds to this description is really the bosh, because the hearth, so-called, is generally filled (or largely so) with molten material, and combustion to any considerable extent cannot take place there in any event, since there is no outlet for the blast in any direction but upward, so that instantly on leaving the tuyeres the blast must pass up into the bosh, where it burns the coke and where most of the final work of the furnace is done. This should obviously be called the "hearth," if any region is to have that name. The habit of thinking and speaking of what goes on "in the hearth" is so universal among furnacemen that it is almost impossible to avoid using the word "hearth" in the sense of the laboratory of the furnace. I shall avoid confusion on this score to the best of my ability, but the reader should be on guard against the ever-present possibility of confusion from this source.

In the introductory chapter of this serial the general outlines and requirements of the process were set forth, and need not be repeated here. In operation the oxygen of the blast is burned by the fuel of the charge to CO in the bosh of the furnace. Theoretically oxygen first burns to CO_2 and then absorbs an additional atom of carbon which converts it into CO, since CO_2 cannot exist as such with carbon except at temperatures far lower than those in the hearth of a blast furnace. Practically the absorption of the additional atom of carbon takes place so quickly that no CO_2 has even been found excepting exceedingly close to the tuyeres and the physical difficulties of taking a correct sample of gas under the conditions existing are so great that little reliable work has ever been done to determine the limit within which the reaction occurs. I was formerly inclined to believe that for practical purposes the formation of CO_2 might be disregarded and the subject considered only on the basis of a direct formation of CO. Professor Howe, however, has pointed out to me that one of the observed facts of practice is well explained by assuming a zone of CO_2 formation at the tuyeres.

I shall later set forth the opinion that combustion of the oxygen to CO is not complete until the gas (blast) reaches the top of the bosh. If this be true and there were not a zone of CO_2 formation then the temperature would be virtually the same at the tuyeres as at the top of the bosh and this we know most positively is not true. There is a zone of intensest temperature right around the tuyeres which drops rapidly at first and then more slowly as we ascend.

These statements do not, unfortunately, depend greatly upon pyrometric measurements at different levels because the conditions of temperature, pressure and dripping iron and cinder within the furnace make such measurements in this zone almost if not quite impossible; the statements depend upon observation of the wear and the evidences of fusion at different levels in furnaces after they have been blown out, and general observation and experience with furnaces in operation.

The amount of heat developed by the combustion of a given quantity of oxygen to CO is only six-tenths of that developed by its combustion to CO_2 and the reaction $CO_2 + C = 2CO$ absorbs a large quantity of heat, hence combustion to CO_2 followed by instant conversion to CO would give a hot zone succeeded by a relatively much cooler one, the condition which we find in practice and for which we have no other adequate explanation. We are ,therefore, compelled to believe that at least part of the oxygen of the blast is converted to CO_2 and remains in that condition long enough to affect the temperature of the tuyere zone through the interval must be measured in hundredths if not thousandths of a second.

As far as the total heat developed in the hearth and the gas discharged into the shaft from the bosh is concerned the combustion to CO_2 has no effect, for in coming back from CO_2 to CO the heat absorbed is precisely the excess developed by consumption to CO_2 over that to CO, and the effect in the final result is therefore zero. Whether any effect of this narrow zone of high temper-

ature and relatively oxidizing condition can be determined may be left for later discussion and we need only say now that the ultimate reaction between the oxygen of the blast and the fuel in the bosh is to convert both to CO, with the development of a certain amount of heat, which is needed to complete the smelting operation, the nitrogen simply serving as a useless load to be carried.

The CO produced in the hearth and bosh passes up through the shaft of the furnace and with more or less help from the solid carbon of the charge reduces the iron from the oxide to the metallic state according to certain reactions which we may now discuss leaving for later discussion the question of heat development.

The functions of these two portions of the furnace, the shaft and the bosh, are quite separate and distinct so much so that we could substitute some other apparatus for one and leave the other unaffected.

For instance, we could produce iron sponge by reduction with a reducing flame in a rotary kiln and introduce it into the "bosh" of a furnace with no shaft above it and there melt the sponge to produce liquid iron and slag.

On the other hand, we could conceivably extract the iron sponge from the shaft of the blast furnace just above the bosh and then melt it down in an open-hearth or other melting furnace.

Many such processes have been tried and some of the attempts have succeeded technically although none of them have survived in actual use for they could not meet the commercial conditions.

They serve a useful purpose here by furnishing proof that the function of the blast furnace is not a single but a double one for the performance of two separate and distinct operations. There is in my opinion no such thing as a fundamentally correct understanding of blast-furnace principles without a full realization of this fact.

The Chemical Principles

The number of reactions which actually take place within the blast furnace is almost unlimited, but those which control its action are relatively few and simple.

These are the reactions between carbon, oxygen, and iron and its oxides, and the reactions which lead to the formation of slag, which are principally the formation of silicates and aluminate of bases, generally in fact almost universally lime and magnesia.

THE REACTIONS BETWEEN CARBON AND ITS OXIDES AND IRON AND ITS OXIDES

There are three well recognized oxides of iron which are in the order of their oxygen contents: Ferric oxide Fe_2O_3, ferric-ferrous, magnetic or black oxide Fe_3O_4, and ferrous oxide FeO.

The former is normally blood red in a color and very slightly magnetic under even the most powerful magnetic field, and is the commonest form in which iron occurs in nature. When hydrated it is brown in color and commonly known as limonite. The second is black and more highly magnetic than any other natural mineral, it is the second commonest form of iron oxide, and that to which iron oxidizes when heated.

The third, ferrous oxide FeO, is unstable under atmospheric conditions, and seizing oxygen from the air instantly returns to the form of ferric oxide.

The oxides of carbon are two, carbon monoxide CO and carbon dioxide CO_2, both gaseous at temperatures even far below that of the atmosphere.

These two elements and their five oxides react with one another at various temperatures according to the following equations in which the modern symbols are used to show that they are reversible:

$$3Fe_2O_3 + CO \rightleftarrows 2Fe_3O_4 + CO_2$$
$$Fe_3O_4 + CO \rightleftarrows 3FeO + CO_2$$
$$FeO + CO \rightleftarrows Fe + CO_2$$
$$3Fe_2O_3 + C \rightleftarrows 2Fe_3O_4 + CO$$
$$Fe_3O_4 + C \rightleftarrows 3FeO + CO$$
$$FeO + C \rightleftarrows Fe + CO$$

It may well be doubted whether the reduction of Fe_2O_3 to FeO takes place by way of Fe_3O_4, and I have always held the most serious doubts as to this point for two reasons: First, the relative complexity of the reaction involving three molecules of one oxide and two of the other, as compared with the extremely simple reactions

$$Fe_2O_3 + C = 2FeO + CO$$
$$Fe_2O_3 + CO = 2FeO + CO_2$$

which involve only one of each. Second, I have always found that the magnetic oxide is less reducible in the furnace than ferric oxide, and it is difficult for me to see how this could be so if ferric oxide has to pass through the magnetic oxide stage during reduction, and I have for several years past rejected that idea.

On the other hand, it is claimed that magnetic oxide is not irreducible in itself, but only because it is extremely dense and non-porous, so that the gas gets no opportunity to work on anything but its exposed surface. That magnetite is generally very dense is certainly true, but even in an extremely fine state of subdivision like roll scale or some of the Lake ores which are composed of flakes almost like graphite this oxide has a strong tendency to scour the furnace, that is, to come through only partly reduced and uniting with the slag forms a silicate of iron which always has an extremely scouring action.

On the other hand, again, Prof. H. O. Hofman of the Massachusetts Institute of Technology has told me that there are several arrests in the curve giving the relation between temperature and deoxidation of iron which indicate the existence of several intermediate oxides between those here noted, and the fact that iron in the course of reduction passes through these subordinate states of oxidation would indicate that it would also pass through the state of Fe_3O_4.

Testimony from such an authority cannot be questioned, but even admitting this as a laboratory condition it does not follow that the same thing takes place in the furnace, and certainly the reputation of magnetic oxide as an ore is not good among furnacemen on account of its well-recognized irreducibility, and I cannot believe that reduction of ferric oxide takes place principally by way of Fe_3O_4.

Carbon unites with oxygen according to three well-known equations as follows:

$$2C + O_2 \rightleftarrows 2CO$$
$$2CO + O_2 \rightleftarrows 2CO_2$$
$$CO_2 + C \rightleftarrows 2CO$$

all of which are reversible.

As the two oxides of carbon occur in the blast furnace in all concentrations from CO alone to CO and CO_2 in about equal proportions and through a very wide range of temperatures, we have the iron and its oxides exposed simultaneously to influences which tend to oxidize them and to those which reduce them.

The question of the temperatures and concentrations of the two oxides of carbon with which carbon is in equilibrium has been experimentally investigated by O. Boudouard in France, and the equilibrium condition of the iron and its oxides in the presence of varying percentages CO and CO_2 at different temperatures has been experimentally investigated by Baur and Glaessner in Germany and reported by them in *Stahl und Eisen* for May 1, 1903.

The work of Baur and Glaessner was extensive and highly creditable. The data given are of great value, but must not be used recklessly, as they cannot always be applied directly to the solution of practical problems whose conditions are frequently very different from those which it is necessary to create in order to secure scientific results. In the present case the scientific investigation has sought equilibrium conditions which are only established after many hours, whereas in the blast furnace the total time of passage of the gas from its entrance at the tuyeres to its exit at the top is only a few seconds, during which equilibrium in most reactions is not even approximated.

We can, therefore, use the valuable diagram of Baur and Glaessner to show what *tends* to happen and what *cannot* happen, but we should be led far astray if we tried to use its results to show the extent to which most of these reactions actually take place.

Their results are given by Sir William Ramsay in his work on "The Phase Rule," from which the following extract is taken as it is the only condensed and yet logical statement extant with which I am familiar of a very complex set of conditions:

"Some of the most important systems of three components in which equilibrium exists between solid and gas phases are those formed by the three components—iron, carbon monoxide, and carbon dioxide—and they are of importance especially for the study of the processes occurring in the blast furnace.

"If carbon monoxide is passed over reduced iron powder at a temperature of about 600 deg., the iron is oxidized and the carbon monoxide reduced with separation of carbon in accordance with the equation

$$Fe + CO = FeO + C$$

This reaction is succeeded by the two reactions

$$FeO + CO = Fe + CO_2$$
$$CO_2 + C = 2CO$$

"The former of these reactions is not complete, but leads to a definite equilibrium. The result of the different reactions is therefore an equilibrium between the three solid phases, carbon, iron, and ferrous oxide, and the gas phase consisting of carbon monoxide and dioxide. We have here four phases, and if the total pressure is maintained constant, equilibrium can occur only at a definite temperature.

"Since, under certain conditions, we can also have the reaction

$$Fe_3O_4 + CO = 3FeO + CO_2$$

a second series of equilibria can be obtained of a character similar to the former. These various equilibria have been investigated by Baur and Glaessner and the following is a short account of the results of their work.

"Mixtures of the solid phases in equilibrium with carbon monoxide and dioxide were heated in a porcelain tube at a definite temperature until equilibrium was produced, and the gas was then pumped off and analyzed. The results which were obtained are given in Tables I and II and represented graphically in Fig. 2.

"As is evident from Tables I and II and from the curves in Fig. 2, the curve of equilibrium in the case of the reaction

$$Fe_3O_4 + CO = 3FeO + CO_2$$

exhibits a maximum for the ratio $CO : CO_2$, at 490 deg., while for the reaction

$$FeO + CO = Fe + CO_2$$

this ratio has a minimum value of 680 deg. From these curves can be derived the conditions under which the different solid phases can exist in contact with gas. Thus, for example, at a temperature of 690 deg., FeO and Fe_3O_4 can coexist with a mixture of 65.5 per cent of CO_2 and 34.5 per cent of CO. If the partial pressure of CO_2 is increased, there occurs the reaction

$$3FeO + CO_2 = Fe_3O_4 + CO$$

and if carbon dioxide is added in sufficient amount, the ferrous oxide finally disappears completely. If, on the other hand, the partial pressure of CO is increased, there occurs the reaction

$$Fe_3O_4 + CO = 3FeO + CO_2$$

and all the ferric oxide can be made to disappear. We see, therefore, that Fe_3O_4 can only exist at temperatures and in contact with mixtures of carbon monoxide and dioxide, represented by the area which lies below the under curve in Fig. 2. Similarly, the region of existence of FeO is that represented by the area between the

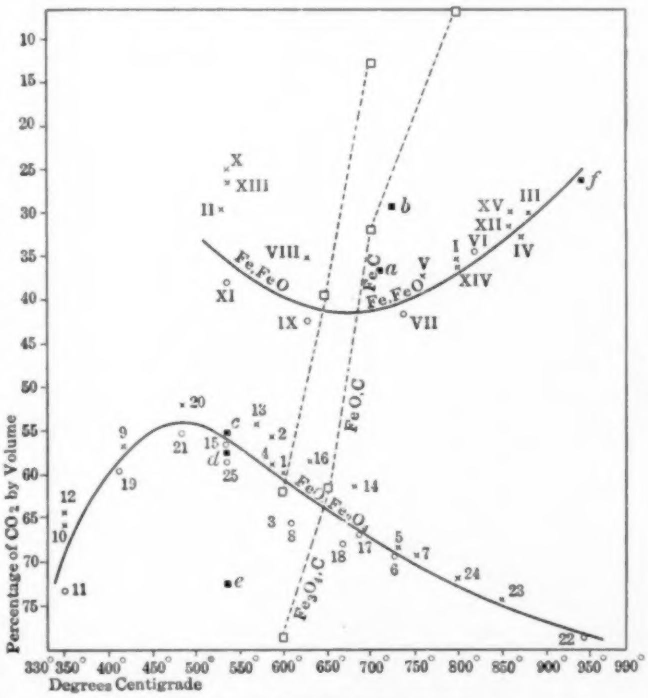


FIG. 2—EQUILIBRIUM CURVE

two curves, while metallic iron can exist under the conditions of temperature and composition of gas phase represented by the area above the upper curve in Fig. 2. If, therefore, ferric oxide or metallic iron is heated for a sufficiently long time at temperatures above 700 deg. (to the right of the dotted line, *vide infra*), complete transformation to ferrous oxide finally occurs.

"In another series of equilibria which can be obtained, carbon is one of the solid phases. In Fig. 2 the equilibria between carbon, carbon monoxide, and carbon dioxide under pressures of one and of a quarter atmosphere, are represented by dotted lines[1].

"If we consider only the dotted line on the right, representing the equilibria under atmospheric pressure, we see that the points in which the dotted line cuts the other two curves must represent systems in which carbon monoxide and carbon dioxide are in equilibrium with $FeO + Fe_3O_4 + C$, on the one hand, and with $Fe + FeO + C$ on the other. These systems can only exist at one definite temperature, if we make the restriction that the pressure is maintained constant (atmospheric pressure). Starting, therefore, with the equilibrium $FeO + Fe_3O_4 + CO + CO_2$ at a temperature of about 670 deg., and then add carbon to the system, the reaction

$$C + CO_2 = 2CO$$

will occur, because the concentration of CO_2 is greater

[1]These equilibria were obtained by Boudouard, *Annales chim. phys.*, 1901 [7], 24, 5. See also Hahn, *Zeitschr. physikal. Chem.*, 1903, 42, 705; 44, 513. Rhead and Wheeler, *Jour. Chem. Soc.*, 1910, 97, 2178.

than what corresponds with the system $FeO + Fe_3O_4 + C$ in equilibrium with carbon monoxide and dioxide. In consequence of this reaction, the equilibrium between $FeO + Fe_3O_4$ and the gas phase is disturbed, and the change in the composition of the gas phase is opposed by the reaction $Fe_3O_4 + CO = 3FeO + CO_2$, which continues until either all the carbon or all the ferric oxide is used up. If the ferric oxide first disappears, the equilibrium corresponds with a point on the dotted line in the middle area of Fig. 2, which represents equilibria between $FeO + C$ as solid phases, and a mixture of carbon monoxide and dioxide as gas phase. If the temperature is higher than 685 deg., at which temperature the curve for $C — CO — CO_2$ cuts that for $Fe — FeO — CO — CO_2$, then, when all the ferric oxide has disappeared, the concentration of CO_2 is still too great for the coexistence of FeO and C. Consequently, there occurs the reaction $C + CO_2 = 2CO$, and the composition of the gas phase alters until a point on the upper curve is reached. A further increase in the concentration of CO is opposed by the reaction $FeO + CO = Fe + CO_2$, and the pressure remains constant until all the ferrous oxide is reduced and only iron and carbon remain in equilibrium with gas. If the quantities of the substances have been rightly chosen, we ultimately reach a point on the dotted curve in the upper part of Fig. 2.

"Fig. 2 shows us, also, what are the conditions under which the reduction of ferric to ferrous oxide by carbon can occur. Let us suppose, for example, that we start with a mixture of carbon monoxide and dioxide at about 600 deg. (the lowest point on the dotted line), and maintain the total pressure constant and equal to one atmosphere. If the temperature is increased, the concentration of the carbon dioxide will diminish, owing to the reaction $C + CO_2 = 2CO$, but the ferric oxide will undergo no change until the temperature reaches 647 deg., the point of intersection of the dotted curve with the curve for FeO and Fe_3O_4. At this point further increase in the concentration of carbon monoxide is opposed by the reduction of ferric oxide in accordance with the equation $Fe_3O_4 + CO = 3FeO + CO_2$. The pressure, therefore, remains constant until all the ferric oxide has disappeared. If the temperature is still further raised, we again obtain a univariant system, $FeO + C$, in equilibrium with gas (univariant because the total pressure is constant), and if the temperature is raised the composition of the gas must undergo change. This is effected by the reaction $C + CO_2 = 2CO$. When the temperature rises to 685 deg., at which the dotted curve cuts the curve for $Fe — FeO$, further change is prevented by the reaction $FeO + CO = Fe + CO_2$. When all the ferrous oxide is used up, we obtain the system $Fe + C$ in equilibrium with gas. If the temperature is now raised, the composition of the gas undergoes change, as shown by the dotted line. The two temperatures, 647 deg. and 685 deg., give, evidently, the limits within which ferric or ferrous oxide can be reduced directly by carbon.

"It is further evident that at any temperature to the right of the dotted line, carbon is unstable in presence of iron or its oxides, while at temperatures lower than those represented by the dotted line it is stable. In the blast furnace, therefore, separation of carbon can occur only at lower temperatures, and the carbon must disappear on raising the temperature.

"Finally, it may be remarked that the equilibrium curves show that ferrous oxide is most easily reduced at 680 deg., since the concentration of the carbon monoxide required at this temperature is a minimum. On the other hand, ferric oxide is reduced with greatest difficulty at 490 deg., since at this temperature the requisite concentration of carbon monoxide is a maximum."

TABLE I—SOLID PHASES: Fe_3O_4; FeO.

No.	Tube filled with	Duration of the experiment in hours.	Temperature.	Percentage of CO_2	Percentage of CO
1	CO	14	600°	59.3	40.7
2	CO	15	590°	54.7	45.3
3	CO_2	16	590°	64.6	35.4
4	CO	24	590°	58.4	41.6
5	CO	22	730°	67.7	32.3
6	CO_2	22	730°	86.1	31.9
7	CO	22	750°	68.4	31.6
8	CO_2	22	610°	64.9	35.1
9	CO	23	420°	56.0	44.0
10	CO	47	350°	65.6	34.4
11	CO_2	46	350°	72.8	27.2
12	CO	53	350°	64.0	36.0
13	CO	18	570°	53.4	46.6
14	CO	19	680°	60.5	39.5
15	CO_2	24	540°	55.5	44.5
16	CO	21	630°	57.5	42.5
17	CO_2	17	690°	65.5	34.5
18	CO_2	17	670°	67.0	33.0
19	CO_2	24	410°	58.5	41.5
20	CO	24	490°	51.7	48.8
21	CO_2	23	590°	54.4	45.6
22	CO_2	4	950°	77.0	23.0
23	CO_2	15	850°	73.4	26.6
24	CO	8	800°	71.2	28.8
25	CO_2	24	540°	56.7	43.3

TABLE II—SOLID PHASES: FeO; Fe.

No.	Tube filled with	Duration of the experiment in hours.	Temperature.	Percentage of CO_2	Percentage of CO
I.	CO	15	800°	35.2	64.8
II.	CO	18	530°	29.1	70.9
III.	CO	13	880°	30.2	69.6
IV.	CO_2	24	870°	32.3	67.7
V.	CO	18	760°	36.9	63.1
VI.	CO_2	16	820°	34.7	65.3
VII.	CO_2	18	730°	41.1	58.9
VIII.	CO	18	630°	34.9	65.1
IX.	CO_2	17	630°	61.6	58.4
X.	CO	18	540°	25.0	75.0
XI.	CO_2	25	540°	36.5	63.5

While the whole series of reactions between iron and carbon and their oxides are graphically portrayed in the chart of Fig. 2 and the accompanying explanation, the form in which the explanation exists is rather condensed and it may be well to run over some of the more important reactions in their relation to the more important phases of the operation of the furnace.

The reduction of iron oxide to iron is performed principally by carbon monoxide, but partly by solid carbon. The more complete is the reduction by CO the more efficient is the operation. The reason for this is not immediately apparent, but will be explained in detail in the next chapter. Part of the CO_2 so formed picks up carbon from the fuel and reconverts itself into CO; on the other hand, the CO is in part split up by what is supposed to be a catalytic action of the iron oxide according to the equation $2CO = CO_2 + C$. The carbon so deposited is in the form of an impalpable powder, which being a solid travels down with the stock, while the gas whose splitting up deposited it, passes on up and out of the furnace. At lower levels where the temperatures are higher and a smaller concentration of CO_2 can remain in equilibrium with carbon this carbon dust is dissolved by the reaction of $C + CO_2 = 2CO$ and passes up again with the gas. We have then a never-ending conflict of conditions in the shaft of the furnace with first one reaction occurring and then the opposite one wiping out its effects.

The effect of having deposited carbon carried down in the solid state through a given zone and carried up as gas to be redeposited again at the top of this zone is to produce an excess of this carbon dust in this zone, which tends to obstruct the openings in the stock through which the gas must pass and causes the furnace to work "tight" in this zone, and most furnaces which slip with more or less regularity in normal operation do so from about the same depth, as measured by the violence of the slip and the effect on the furnace. Such slips throw out huge clouds of black dust which travels high in the air; part of this is undoubtedly partly reduced iron, but much of it is the carbon dust which caused the slip in many cases.

While discussing the subject of the conflicting conditions existing in the shaft of the furnace it is well to call attention to the fact that the stock is charged in roughly horizontal layers, first one of fuel, then one of ore and stone, one of which tends to reduce the CO_2 already formed to CO, while the other tends to oxidize the CO to CO_2. These layers are only a foot or so in thickness, and the time of the passage of the gas through them must be measured in hundredths of a second so their effect is like that of waves of alternating forces, one set trying to hinder, the other to assist in bringing about the equilibrium which the broader conditions of temperature, etc., are trying to establish. This in itself would constitute a sufficient reason for the impossibility of predicting the conditions which will prevail under any given circumstances by the equilibrium diagram.

The Real Controlling Factor in the Composition of the Top Gas

After all the laborious and painstaking investigations of this subject which have been made we come now to the astonishing fact that the composition of the top gases is not a cause but an effect, and that important as are the detailed reactions I have so briefly described the composition of the top gas does not depend on them primarily at all, and at least three-fourths of all the work done on that subject has been wasted.

The reason for this will be clearer after we have discussed the heat equation of the furnace, but it will be well to explain it now and then return to it again later if desired. The reason is this: The ore to produce a ton of iron contains a certain definite quantity of oxygen; ferric oxide contains 70 per cent Fe and 30 per cent O, magnetic oxide Fe_3O_4 contains 72.4 per cent Fe and 27.6 per cent O, but commercial pig iron only contains about 94 cent Fe, and this being accompanied by 35.8 per cent of its weight of oxygen in the case of magnetite and 40.3 per cent in the case of ferric oxide, the oxygen per unit of pig iron is 33.7 per cent in the first case and 38 per cent in the second. These are perfectly definite relations not subject to furnace conditions or other qualifications.

We shall presently see that to keep the furnace hot enough in the hearth to run, a certain amount of fuel must be burned in the hearth for every unit of iron produced, the amount having nothing to do with reduction or in a general way with chemistry at all, but being a plain matter of heat, as the case of melting ice or any other solid. Now this carbon is burned to CO and nothing else; the CO_2 phase is, as I have explained, a transient one without effect on the final result. Thus we have a certain definite amount of carbon monoxide depending entirely upon hearth conditions and a certain definite quantity of oxygen added to it, as the oxygen is removed from the ore during the upward passage of the gas. It is obviously no problem in chemistry, but only a rudimentary one in arithmetic as to what the result will be in the composition of the gas at the furnace top.

But this statement which would settle so many problems if it were unreservedly true is subject to a certain limitation. The amount of carbon which must be burned in the hearth is not the same as the amount which is charged into the top, nor does it even bear a fixed relation with it, because the carbon charged, from the moment it enters the furnace, is subject to the solution by the CO_2 in the gas, and to direct oxidation by the oxygen of the ore and these influences, particularly the latter, as I shall presently show, are extremely variable, so that though the oxygen liberated and the carbon burned in the hearth per unit of iron produced are definite quantities which by themselves would give a top gas of a certain definite composition, they are not the sole determining factors; a secondary but none the less considerable influence is exerted by the carbon dissolved before it reached the tuyeres. This constitutes a variable addition of carbon to the definite composition of gas produced by the two main factors.

The Solution of the Carbon

The flux used for blast furnaces is universally either carbonate of lime, calcite or carbonate of lime and magnesia, dolomite, or a mixture of these two. These carbonates are broken up by heat, the carbon dioxide beginning to come off at a temperature of 800 deg. Fahr. or so, and not being all driven off, especially in the case of dolomite, until it reaches a temperature almost twice as high.

This is the range of temperature in which carbon dioxide attacks solid carbon very actively, and as a consequence the carbon dioxide liberated by the flux carries off enough carbon to restore approximately the equilibrium set by the conditions of temperature and the relative strength of the reducing and oxidizing influences in that zone.

This not only constitutes a loss of solid carbon, but a loss of heat as well, since the reaction $CO_2 + C = 2CO$ represents an absorption of heat of $14750 - 2 \times 4375 = 6000$ B.t.u. per pound of carbon dissolved. The carbon dissolved would obviously be equal to that in the limestone from whence the CO_2 comes, if all the CO_2 of the flux were reduced to CO, and as carbon constitutes 12 per cent of pure limestone (13.8 per cent of pure dolomite) and as the ratio of CO to CO_2 to which it is reduced is approximately 2:1 or two-thirds CO, we can see that 8 per cent to 9 per cent of the weight of the flux is the quantity of carbon dissolved and carried out the top of the furnace by the CO_2 of the flux. In proof of this fact gas samples taken from a point well below the stock line show a higher content of CO_2 than simultaneous samples from the furnace top showing that the CO_2 evolved by the flux was actually reduced to CO. I believe that this experiment has been made quite frequently, and I myself have made it with results which left no room for doubt.

The obvious suggestion is that the flux should be "burned" so as to drive off its CO_2 before charging into the furnace, and this has in fact often been proposed, but has never been done to any great extent. This failure may be due to inertia and the desire to avoid any additional operation at the blast furnace, but it has a certain justification in that most furnaces have a considerable excess of heat in the shaft and the limestone can be calcined with this without burning any fuel for this purpose. In many, if not most, cases this results in ultimate economy in dollars and cents in spite of the fuel dissolved by the CO_2. We can discuss this subject better when dealing with heat balance of the furnace in the next chapter.

A third source of solution loss is the contact of the ore and fuel and the direct reduction which results according to the equation $Fe_2O_3 + C = 2FeO + CO$ and $Fe_2O_3 + 3C = 2Fe + 3CO$.

These reactions take place freely throughout a wide range of temperature as shown by Fig. 2, and therefore every point of direct contact between ore and fuel is a possible point of direct reduction and solution loss. It would appear at first sight that this was precisely what we wanted, but when we come to deal with the thermal equations we shall see that it results in a very real loss, and I shall endeavor to show that the increase in the number of points of contact between ore and fuel accounts for the increase in the fuel consumption of fur-

naces which has resulted when their burden has been changed so largely to fine ore.

The conditions which lead to solution losses by any or all three of these methods are important and worthy of careful study, even though the theoretical laws of ore reduction do not control the action of the furnace to anything like the extent believed by some.

The Action of Hydrogen and Volatile Hydrocarbons

All furnace fuels contain a certain amount of combustible hydrocarbonaceous matter not driven off when the fuels were produced, but volatile at the temperature of the blast furnace, and as these frequently if not always contain considerable quantities of hydrogen their effect on the composition of the top gases is greater than their absolute quantity would lead one to suppose.

The quantity of volatile combustible matter in anthracite and coke is ordinarily 2 or 3 per cent, although it may go higher than this in some cases.

No analyses of this volatile combustible matter in anthracite and coke are at hand, and in ordinary cases and for ordinary purposes their quantity is not sufficient to exert an important influence. But in charcoal the case is very different; the volatile matter is about 30 per cent of the total weight of the fuel, and by far the larger proportion of it is combustible, about 50 per cent by volume hydrogen and about 15 to 20 per cent are methane or other hydrocarbon containing the same amount of carbon and hydrogen as that amount of methane in addition to some 10 or 15 per cent CO.

This is very important because the first two of these gases are extremely active reducing agents even at quite low temperatures, and the quantity of oxygen required to satisfy them is much greater than is required for CO or carbon. Hydrogen requires eight times its own weight of oxygen to convert it to water, and methane to convert it to water and CO_2 requires four times its weight of oxygen, as compared with one and a third times its weight to convert carbon to CO or two and two-thirds to convert it to CO_2. Moreover, about 30 per cent of the product of combustion of methane and all that of hydrogen is water vapor which mingles with the water vapor from the stock and completely disappears as a determinable quantity in the top gases.

Hydrogen is active as a reducing agent at temperatures lower than those required for much activity by carbon monoxide, and therefore the presence of this gas may be very beneficial in certain special cases. We have, unfortunately, no such reliable investigations of the reducing action of hydrogen as those of Baur and Glaessner for the oxides of carbon, but it is well known that the reaction is reversible; steam passed through a red-hot iron pipe is broken up, the oxygen attacking the iron of the pipe and hydrogen being set free. On the other hand, hydrogen will reduce iron oxide to metallic iron at quite a low temperature. But no data exist as far as known to me on the equilibrium percentages of hydrogen and water vapor at different temperatures in the presence of iron and carbon and their oxides.

The reversibility of the action of hydrogen will appear very strikingly in the next chapter; it will be seen that a chemical balance for the ingoing and outcoming materials of a charcoal furnace cannot be made unless the very considerable proportion of the total oxygen which disappears by combination with hydrogen be brought into account, while in coke furnaces it will be seen that hydrogen is produced by the decomposition of water, not only in the hearth of the furnace but also on a much more extensive scale in the shaft.

The reactions which are probably responsible for this result are

$$H_2O + Fe \rightleftarrows FeO + H_2$$

and

$$H_2O + CO \rightleftarrows CO_2 + H_2$$

both of which are reversible, as indicated.

The second is the typical reaction of the steam-blown gas producer.

The factors which control the direction in which these reactions take place are probably temperature and concentration of CO_2, but the indications are that temperature is the more important because hydrogen is consumed in the charcoal furnace, with its low top temperature, in spite of fairly high concentration of CO_2, while it is produced in the coke furnace, with its much higher top temperature, in spite of the low concentration of CO_2.

There is, however, much more ore and, therefore, more oxygen in proportion to the top gas in the charcoal furnace, and this may account for the oxidation of the hydrogen in that case.

These are some of the factors which affect the situation, but the conditions which control we frankly do not know.

The Carburization of the Iron

This is a subject of the details of which we know relatively little. Iron absorbs carbon eagerly up to between 1 and 2 per cent in the solid condition if exposed for a sufficient length of time at a high temperature, and in the liquid condition reasonable exposure to incandescent carbon will raise the latter element to about 2½ per cent in a neutral or slightly oxidizing atmosphere, but it is difficult to raise the carbon contents of a bath of steel beyond this limit by any means commonly available. Even in the electric furnace difficulty has been found in commercial operation in raising the carbon to the range which is commonly found in pig iron.

The explanation for this probably is that the conditions of exposure in the blast furnace are exceedingly favorable. The iron sponge, produced by the breaking up of the iron ore into powder under the action of the reducing gases and the removal of the oxygen from this powder, probably absorbs some carbon from the gas or the fine carbon precipitated from the gas before it reaches the zone of fusion, but not much is known about this.

After fusion the iron forms into drops presumably on the surface of the pieces of coke and then trickles down through the coke which constitutes the only solid contents of the bosh and hearth.

The progress of the iron is probably very slow at first, because until it is carbonized its temperature of fusion is that of steel, several hundred degrees higher than that of cast iron, while the temperature of the upper part of the bosh is much lower than that around the tuyeres. It may even be that the iron descends through the upper part of the bosh in the solid condition attached to the coke and is carried down by the latter in the solid condition. Then as it becomes more thoroughly carbonized and the temperature rises, it melts and completes the journey by trickling, but even this constitutes a slow descent because the surface of the coke is always porous and therefore rough, and the pieces of coke being in close contact with one another the path of the trickling iron is rough and tortuous.

Another important factor in retarding the progress of the iron and giving a chance for carburization is the high velocity of the gas upward, which must act to some extent like the up-blast through a shot tower in retarding the velocity of the liquid metal downward.

The conditions controlling carburization are not by any means thoroughly understood, and it is a lamentable fact that so little reliable work on the determination of carbon in cast iron has been done that our knowledge of the quantity of carbon in different irons made under different conditions is much less comprehensive than that of any other branch of the chemistry of iron.

We do know, however, that by the use of extremely high temperatures in the experimental electric furnace Moissan and more lately Witorff have succeeded in producing compounds of iron and carbon higher in the latter element than have ever been produced industrially. The compound Fe_2C seems to have been definitely identified as one of these products, and this contains 9.7 per cent of carbon. It is, therefore, probably safe to say that the higher the temperature, other things being equal, the more carbon will be absorbed. It is also probably safe to say that the more carbon in the hearth per unit of iron produced, other things being equal, the greater will be the carbon absorption.

The amount of excess heat in the hearth is probably a factor of much importance, and the nature of the fuel used may be of predominating importance since with charcoal fuel the carbons in the iron produced under certain circumstances rise to 4.50 per cent or more, although the temperature in the hearth is low relatively to that of a coke furnace which produces iron commonly running about 3.70 to 4.10 per cent carbon.

This subject will be further discussed in dealing with furnace operation and the quality of iron.

Manchester Meeting of the Society of Chemical Industry

The annual meeting of the Society of Chemical Industry was held in Manchester from July 14 to 16. According to the report of the Council, read by the secretary, Mr. C. G. Cresswell, the number of members is 4017.

There were less social functions than in former years, but more papers, mostly concerning the conditions and prospects of the British chemical industry and its relation to the chemical profession.

Presidential Address

Prof. G. G. HENDERSON, in his presidential address, said: "Since the outbreak of the war there has been much discussion concerning the present position and the future prospects of the chemical industries of this country, and I earnestly hope that the serious consideration which has been given to the subject will have at least one result—that we shall refrain from talk and proceed to action. We have been made to realize more clearly than ever before that during the last forty years chemical industry in Germany has made marvellous strides in advance, while in this country [England] it has by comparison stood still or even gone back. We have to admit that certain branches of applied chemistry, particularly the manufacture of dyestuffs, of synthetic drugs, and of organic compounds and fine chemicals in general have passed almost wholly out of our hands, or rather have never been taken up to any notable extent in this country. We cannot deny that the Germans have with energy and success developed on the industrial scale many scientific discoveries, such, for instance, as the various methods for the fixation of atmospheric nitrogen, while we have done little or nothing in that direction. Even our former supremacy in the manufacture of heavy chemicals has been seriously attacked. These are the facts."

Professor Henderson thinks there are two main causes of British lack of progress. "Firstly, we have failed to realize that 'scientific research work carried out in the laboratory, is the soul of industrial prosperity'—that modern chemical industry must of necessity be based upon research if it is to meet with success. This axiom may indeed have been tacitly accepted, but, speaking generally, it has not to a sufficient extent been made a guiding principle in our chemical industries. In the second place, there has not been in the past a sufficiently close and intimate interchange of information and opinions between manufacturers and professors of chemistry; in fact, most unfortunately for both manufacturer and teacher, the attitude has rather been one of mutual aloofness and reserve."

To rectify these errors Professor Henderson advocates the scheme of Industrial Fellowships, more or less on the lines of that successfully inaugurated by the late Kennedy Duncan in connection with the Universities of Kansas and Pittsburgh. "The essence of this eminently practical idea is that any manufacturer who desires to have some technical matter investigated applies to the chemistry department of a university or technical college for the service of a chemist qualified to prosecute research, and undertakes to provide adequate remuneration for a period of one or more years; the work is done in the chemistry department under the general superintendence of the professor, and, if necessary, facilities for large scale experiments are provided by the manufacturers."

As to the training of chemists for technical posts, Professor Henderson points out that opinions differ but may be grouped into three categories. "Some teachers appear unwilling to admit the possibility of the existence of the chemical engineer, and maintain that the chemical student requires nothing more than a sound scientific training to fit him for an industrial career, and that, if only he is a good chemist, he will be able after he enters a chemical factory to grapple with and overcome the special problems involved in the design and construction of apparatus and plant for chemical operations in any case. Others, again, hold that in addition to a thorough scientific training the student should receive such a course of instruction in chemical engineering as can be given in any teaching institution properly staffed and equipped for that purpose. Lastly, a few teachers apparently incline to the opinion that the student after acquiring a comparatively elementary knowledge of general chemistry should proceed at once to specialize in some branch of chemical technology."

This last method Professor Henderson considers to be wrong in principle and futile as regards results: any specialization in chemistry should be post-graduate work. The other two rival methods of training stand upon a different footing, and each can be defended by cogent arguments, but Professor Henderson's own experience leads him to advocate the second course.

Co-partnership in Chemical Industries

In a paper on this subject by Sir WILLIAM LEVER, it is pointed out that the present war has given Great Britain an awakening. British industries will be stimulated to organize efficiency as a result of the war. Yet the attainment of efficiency in mechanical appliances, in chemical knowledge, in banking arrangements, is not sufficient, but the human element must be taken care of. For this reason the author recommends co-partnership in the chemical industries—not simply profit-sharing, but also loss-sharing.

"Just as it is found in practice that the debenture holder, and to almost an equal extent the preference shareholder, take little or no interest in the undertaking in which their capital is invested, so it is found that the sole impulse and inspiration for development, growth, and activity in industries springs from direct interest in the results as represented by the holding of ordinary shares with possible profits or losses. When the board of directors are simultaneously ordinary shareholders, the greatest amount of efficiency, development and activity can be attained. The very fact that management and labor are often relegated solely to the position of debenture holder has reduced the efficiency

of management and labor and their interest in the undertaking in which they are engaged to the level of that of debenture holder, which, as we all know from experience, is, practically, a minus quantity." . . .

"I know of no industry to which the system of co-partnership applies with greater force than to the chemical industry. A British chemical industry, founded upon the principles of co-partnership, with employees trained and instructed as to what these co-partnership principles meant, and realizing the opportunities co-partnership offered them, would surely possess employees superior to those of competitors in Germany, or elsewhere, under mere wage and salary conditions."

It is more difficult in the chemical industry than in any other industry to assess the services of each member of the staff, whether as inventor, developer of the inventions of others, or organizer, or rank and file employee carrying on the routine process of production.

The following rules on co-partnership should be always kept in mind:

Profit sharing or co-partnership must not degenerate into charity or philanthropy. Its objects must be the increased success of the undertaking, with increased prosperity for all connected with it. It must not place management in the position of servant to labor through liability to criticism and censure. It must ensure to labor freedom from interference of management in the enjoyment of the benefits derived from profit sharing. It must possess greater stability than a mere system of bonus cash payment. Its benefits must be felt by the wives. It must have a distinctly elevating tendency on management and labor, raising them in the social and intellectual scale, and increasing their power for enjoyment and happiness as well as their power of usefulness. Control must remain with those who find the cash capital.

The whole basis of profit sharing or co-partnership cannot be other than enlightened self-interest for both capital and labor. Any other idea would be destructive to the self-respect of the employee, and lead to confusion from the point of view of capital. Philanthropy is own sister to charity, and charity is the mother of pauperism. There is no room for philanthropy in business, there is no room for maudlin sentiment; but there is ample room for a better and improved industrial relationship between capital and labor, one in which labor can become, equally with capital, interested in the results of the undertaking.

Research and Chemical Industry

Dr. M. O. Forster in a paper on this subject deplored the chasm between college and factory and pointed out that this estrangement proceeds in a vicious cycle. "If the manufacturer is not disposed to employ chemists on his premises, he could at least provide them with raw material or with problems which, if successfully handled and solved, would not only help him, but would give the instructors in that college the scent for technical inquiries. This would provide the first requirement in a course of genuine technology, a stimulus, and I am convinced that scores of chemists have been lost to industry from the absence of this connecting link. The young demonstrator, anxious and willing to work at anything useful, would be thrilled and exhilarated by a kilogram of waste material from Messrs. X and Y's manufacturing process, and a request to ascertain whether any valuable constituent was being thrown away; his mind would be directed forthwith into that particular field of industry, and whatever he found, even if it amounted to nothing, he would insensibly become potentially more useful to Messrs. X and Y, so that if these gentlemen ever did summon up courage to employ a chemist he, or the post-graduate student who had helped him, would be a suitable man to engage."

Dr. Forster said the first necessity for a closer union between research and industry is the development of a healthy public opinion on the subject of acquiring knowledge in general, scientific knowledge in particular, and more important than either, because it covers both, national wisdom. "In order to do this, speaking bluntly, our governments must advertise scientific methods of business and education by the employment of such methods in their own operations. In the establishment of such public opinion an important place should be given to the work which chemists do, the part which chemistry has played in the national economy, and the possibilities offered by a wider application of chemistry to industry, in order to attract to our ranks that type of young man which is able to use a chemical training as a weapon for making chemistry pay.

"Next, although many enlightened manufacturers already make good use of chemistry, their numbers must be increased, and the newcomers must not be too quickly discouraged by what may seem initially an unprofitable investment. It is not to be expected that when the war is over there will be any mitigation of Gottstrafe British Dyes, Ltd., and any other industry which ventures to raise its head, and the situation must be faced with resolute courage and all the resources of our people, both material and intellectual.

"In the next place, by some process which I cannot clearly foresee, but which must inevitably depend upon sympathetic pharmaceutical agreement, a means must be found by which the respective activities of chemistry and pharmacy may be differentiated in the public mind, so that existing vague ideas on this matter may be clarified. Concurrently with the removal of these motes from the eyes of other people, we must pay attention to the beam or two in our own. If the operation is carried out cheerfully, courageously, and conscientiously, our scientific descendants may have to bless this era as one of chemical regeneration, even if they do curse the ill-wind which wafted it to this country."

Finally Dr. Forster suggested the formation of a chemical intelligence department by the Board of Trade for the collection, tabulation, classification and distribution of chemical information, presentation of new problems, etc.

Development and Control of Industry by Public Influence

Prof. Henry E. Armstrong, in a paper on the subject, said: "The one chief lesson of this terrible war is the need of bringing home 'the idea of science' to the public at large; experts they can never be, but some respect for it they can acquire, and to insist that it be used regularly and systematically in the service of the country. It is clearly our duty to persist in urging its infinite value.

"All this by way of introduction—just to make clear my one thesis: that charity begins at home; that this body needs to wake chemical industry. Almost supine hitherto, you have allowed others to tinker with matters which primarily should be your concern."

Union is strength—is the motto of engineers. Medical men occupy a similar position; lawyers also; both professions are organized on trade-union lines. "But those who rate themselves scientific—the academic party as a whole—are an unorganized rabble, so individualistic, self-centered and unsympathetic that what is one man's meat is almost necessarily another man's poison. This is both our strength and our weakness, but we shall never win through until we can combine strength with

weakness. The lesson of the moment, the lesson a lifetime has taught me, is that chemists, too, must become professionals, and like others sell their services, not give them. We have not yet learned the lesson of the world; that people only appreciate that which they pay for; that the value of a thing is not appreciated until it has been sold freely. Academic chemists ought not merely to be allowed and encouraged, but almost required to work for payment, as consultants, like the engineers. The professor pure and simple should disappear." . . .

"One main reason why we are so much behind in some of the chemical industries is that the instruction given in our schools has been far too academic in character. It cannot be said too definitely, either too loudly or too widely, that chemistry has not attracted gentlemen—men of general mind, good presence, and real ability—in sufficient numbers into its ranks during many years past. We want much of the material that now degenerates into briefless barristers. Such material properly trained would be of worth, and command good pay."

Professor Armstrong criticized the work done by various committees appointed during the last year in Great Britain. The primary mistake was in appointing lawyers to controlling positions on these committees. Such men, however able and eminent, cannot have any real expert feeling on technical problems outside their own profession, and where there is no expert feeling, no proper sense of "technical effect"—to use Faraday's expression—there can be no "proportionate judgment" exercised.

"We have to bear in mind that the success of German chemical industry is due to two causes: Firstly, to the fact that the German universities are practical institutions—not collocations of compiling colleges—properly supported by the state and in touch with the educated community. The idea of science is abroad in Germany, though 'science' is not more taught in the schools than it is here. Science, however, is respected, and has acquired a money value in public eyes because it has been made real; the company promoter has been kept in subordination, and it has been shown that trust can be placed in those who undertake scientific ventures. . . . The second and true cause of German success is that the factories are in the hands of experts; moreover and especially ample provision is made for carrying out all necessary and desirable research work within the factories in well-formed laboratories, this being possible because a supply of properly trained men is to be had from the universities."

Professor Armstrong recommends that the government should levy an "insurance tax" on all industries in which the maintenance of research department is necessary and to apply the income from the tax to furthering research work.

"*Our plain duty in this society is to organize ourselves and when we are organized to claim the right to guide the government.* But unless the representatives of science subordinate their individualism, sink their differences and form a complete coalition of their forces, no public impression will be made. The task before us is indeed colossal. Before the war, Germany had control of the Russian market. It will be long before she will regain this, and here will be our opportunity—if our schools take Latin and Greek plays out of their bill and stage Russian instead, and if they add Spanish, we may have some chance in South America also, if meanwhile the Americans do not seal the market against us. The competition we shall have to meet outside Europe, especially in the East, will be greatly intensified, because this will be the chief market open to Germans. I have seen enough recently of German organization of trade in the East to realize that ours did not compare with it in efficiency."

Research in Technology

Dr. CHARLES C. CARPENTER, in a paper on this subject, emphasized that the chemical industry of to-day cannot make progress without research.

"That research must commence with the chemist goes without saying. Circumstances have, however, changed since the inception of the first great chemical processes. The technical demands made by modern manufacturers are much more extensive and exacting, and sole reliance upon the chemist would be fatal to the realization of success. Sooner or later the aid of the technologist must be called in. His equipment for the task is on a very different footing from that of his confrere, for it must be carried out on the large or working scale. Now surely here is an overwhelming case for localized centralization if one fact, and one fact only, is borne in mind. It is not from or among themselves that the greatest competition is to be feared, but from producers over the seas already organized. Let, then, every special industry build up its own schools or institutes of technology, not only to provide training for workers, but so fully equipped with resources that problems of all kinds can be submitted to them for research.

"It may be said that one manufacturer would be contributing to progress made by another. That may be true, but it would be better for him to put a small tax upon his profits for such a purpose than, by want of united effort, risk losing his trade altogether. It may be argued that the risk would be a great one in reposing so much confidence with the principals of such organizations. But if we distrusted our physicians we should run the risk of being decimated by disease. Is there one in a thousand who does distrust his adviser in sickness? Why should the physicians of industry be less honorable or disloyal? Such institutions as suggested would be clearing-houses for troubles to which manufacturers would automatically turn, whether perfecting an old process or working out a new.

"If as a nation we are to emerge successfully from the industrial battle which is awaiting us, we must pool not only our difficulties but their solution. When it is required to start new processes or adaptations, it will never do for each manufacturer to proceed as is now the case, viz., start *de novo* and work out for himself methods of its industrial application which are already known and used in other directions. He would get it from the institutes. If, as in some cases, the information as to certain methods of plant were confidential, he would be put into communication with the users, and matters might then be left to develop on ordinary business lines."

Chemical Engineering

Dr. G. T. BEILBY, in his paper on this subject, said that engineering has always had a definite place in chemical manufacturing, but the degree and kind of engineering skill which has found a place in the older chemical works has been frequently not of a very high order.

"One of the special features of large-scale chemical apparatus is the heavy depreciation to which it is subject and the need, therefore, for continual renewals and repairs. The skilled engineer who has been accustomed to the construction of high-class prime movers or mill machinery may be very ill-fitted to design and keep in repair the short-lived apparatus of the chemical works. A more adaptable but rougher type man is required, and these needs have produced a rather special kind of man, the 'chemical works engineer,' rather than the 'chemical

engineer.' If these facts are kept in mind we shall not find it at all surprising that a chemical works plant, especially in the older works, often has an improvised appearance which suggests either that the engineer in charge is actually slovenly or that he knows so well the temporary character of the work that he does not think it worth while to conform to the ordinary decencies of engineering design and construction! Tumble-down apparatus in only too apt to react on the processes which are carried on in it, and slipshod working is the outcome. The moral effect of rapid destruction of plant is certainly bad; hence the enlightened manufacturer is willing to make many sacrifices to secure more enduring forms of plant.

"Apart from the special characters which are due to the necessity for frequent renewal, there is no doubt that the influence of the chemist has had a definite effect on the design of chemical plant. A former colleague of my own, who had himself made splendid contributions to the improvements of the apparatus used in one particular industry, could find no more contemptuous way of expressing his opinion of any piece of apparatus of which he did not approve than to call it a 'chemist's job.' Of course, the chemist did sometimes get back on the engineer, if an elaborately designed piece of apparatus failed to give satisfactory results from a process point of view! In this case, unfortunately, any attempt at a *tu quoque* was more than ordinarily ineffective, as an 'engineer's job' was just the kind of job the constructor desired to make! It is not easy to define or characterize these two kinds of job by any simple definition. Chemists' apparatus is more the result of opportunism than of deliberately thought-out design. Contingencies are provided for as they arise, and initial mistakes in design are apt to be met in a partial or temporary way.

"The origin of the chemists' type of apparatus is found in the chemical laboratory, where it has generally been the aim of the professor to develop in his students a certain kind of individual resourcefulness. When the chemist needs to increase the scale of his apparatus, he naturally follows the type of construction to which he is accustomed, and even when the increased scale gets beyond the resources of the blowpipe table and the cork drawer, his ideas flow along the old laboratory lines. When the increase in scale is so considerable that it becomes necessary to call in the help of the engineer and his craftsmen, the designs proposed by the chemist still show their laboratory origin. The quick adaptability of the plumber's methods attract him rather than the engineer's carefully arranged series of steps from the drawing office through the pattern shop, the molding shed, and the foundry, to the machine shop. In pioneering work a 'chemist's job' is often the most suitable to use, but when the stage of steady manufacturing has been reached, all the resources of the drawing office and workshops should be devoted to the design and construction of suitable apparatus."

The procedure in the design of new apparatus in modern chemical works where sound engineering principle are allowed their proper might, is sketched by the author.

"In the modern organization there is room for the research chemist of high and wide attainments, for the scientifically trained engineer, also of wide attainments, and for a type of professionally trained man who is the natural medium of interchange between these two specialists. This intermediary is the chemical engineer. He must be a man of special aptitudes inasmuch as *he must have grasped the chemist's point of view as well as the engineer's*. The chemist thinks and works in terms of atoms and molecules and the laws which govern their combination. The engineer thinks of matter in masses which can be molded to his will by the craftsman, or of mechanical or electrical energy which can be generated, controlled and measured by machinery. The chemist is the master and director of his own operations, which he can, for the most part, carry out with his own hands. The engineer loses his direct hold on his operations whenever his ideas have been fully committed to paper in the drawing office. It is his special function to organize the labors of many workers.

"A certain number of men are able to enter fully into the spirit which actuates both types of expert, the chemist and the engineer; they can resist the particular exclusiveness of each, while giving to each its due weight. These are the naturally gifted chemical engineers who in one sense are 'born, not made.' In our colleges and universities the best that we can do for men of this gifted type is to give them the best possible opportunities for an all-round development of their powers. For the average men, we ought to provide a properly organized course of training in theoretical and practical chemistry, physics and mechanics, on professional, not on purely academic, lines.

"Our colleges have thus two distinct functions to perform, and it is best that this should be clearly recognized, first to allow the future leaders in applied science to come naturally to the top during their training, and second, to prepare a large number of well-trained professional men for the organization and development of industry. The ideal for these men must be a professional one. It is to be feared that the making of practical chemists has suffered severely from a fallacy—namely, that all students ought to aim at being pioneers in some branch of their science. Science and industry alike call aloud for *real pioneers*, for without these the highest type of progress cannot be realized. This call, however, cannot be met by the premature stimulation of 'originality' in men of very ordinary endowment. The effect of this stimulation is not merely futile, it is positively mischievous, for it raises an ideal which for the ordinary man is quite inappropriate during his preparation for a life of serious practical endeavor. In conclusion, I must repeat the statement of my belief that the phenomenal development of chemical industry in Germany has resulted much more from the large command of chemists and engineers of sound professional training and ability than from the possession also of an even larger supply of research chemists of mediocre ability."

A general program of the engineering society conventions and International Engineering Congress, to be held in San Francisco, Sept. 16-25, 1915, has been issued for the information of those expecting to attend. A copy may be had on application to W. A. Cattell, Secy., 417 Foxcroft Bldg., San Francisco. The program covers in outline the conventions of four of the national engineering societies, the meetings of the Congress, and the excursions planned.

The production of bauxite and the consumption of aluminium in the United States in 1914 were the largest ever recorded, according to the U. S. Geological Survey. The output of bauxite was 219,318 long tons, valued at $1,069,194, as compared with 210,241 long tons valued at $997,698 in 1913. The principal producing States were Alabama, Arkansas, Georgia and Tennessee. Arkansas produced more than 80 per cent of the output. The principal uses for bauxite are the production of aluminium, aluminium salts, bauxite bricks and such artificial abrasives as alundum. The quantity of aluminium consumed in the United States in 1914 was 79,129,000 lb., against 72,379,000 lb. in 1913. In 1884 the production was but 150 lb. The consumption of the metal is constantly expanding.

Industrial Energy as a Military Weapon*

BY J. R. FINLAY

At the beginning of the present European war I had believed that industrial energy would prove to be the decisive factor in this present struggle, and that this energy might be fairly represented by the use and production of coal and steel. Part of this proposition is now recognized by the public; the other part is not. It is now seen that the nations of Continental Europe that are facing Germany, namely, France, Russia and Italy, are no match for Germany in the production of the necessary equipment and munitions for fighting. I argue that it is equally probable that the whole combination of the Allies, including England, is deficient in the capacity for organizing and for utilizing equipment. I am disposed to believe that the second element is more important than the first, because it requires time to develop. You will understand that I am working on the supposition that military success arises from the same kind of development as industrial success. It will take some time longer to prove this.

The idea is abroad that Germany may be conquered by the Allies if the latter will buy enough copper and other munitions. The reality is that the buying of supplies is a comparatively insignificant part of the problem. To take an industrial comparison, let us suppose that the plants of the United States Steel Corporation were supplied, complete, to Russia, without the organization as it exists to-day. What use could Russia make of them?

I do not mean to imply that the individual Russian is necessarily inferior as a workman, or as a man, to the individual American. That is one of the difficulties in understanding this present situation. Each of the great nations and races of mankind is able to furnish human material that can compete on even terms with that of any other nation. But I think you will recognize quickly that it would take the Russians many years to make any adequate use of the plants of the United States Steel Corporation. It is hardly worth while to go into details. The operation of those plants, including mines, steamships, railroads, rolling mills and factories of all kinds, requires the development of a vast amount of specialized labor; it also requires a great deal more than that, namely, a slowly developed and highly organized control. The plans and the execution of them must be tested by competition with rivals. The organization must know the fields in which the products, when made, can be sold and utilized. It would be easy to dwell on this subject a long time, but I think you will soon conclude that the plants of the United States Steel Corporation would never reach anything like the effectiveness in Russia which they have in this country, until the Russian nation is developed industrially to such an extent that it can meet such an organization on even terms. In other words, other industries, all of the industries in the country, in fact, would have to be developed in a substantially equivalent manner. This certainty cannot be accomplished over night, nor during the probable continuance of any war. It is a matter that requires nothing short of the industrial organization and development of the nation. A generation, or even two generations, is a short time for such an accomplishment.

Dropping this subject for a moment, it seems to me that we should stop and discuss fundamentals a little.

One such fundamental is that our political ideas and most of our beliefs and prejudices date from the time when the steam engine was unknown. I believe that economic changes have taken place in the leading civilized nations without producing, as yet, the inevitable change in political and social ideas. We are facing facts which we do not recognize, or at least, which are not recognized by the public. We go through forms of thought and attach ourselves to certain prejudices that will not stand the analysis of modern actualities. Some of our political sentiments are like the buttons on a dress coat, which were put there originally to attach swords to, because gentlemen wore swords, and the dress coat is the coat of a gentleman; but there is no longer any actuality in the sword as a weapon, either social or military. The fact that we like to see buttons on a dress coat is a mere sentiment which does not change in the least the relative efficiency of the sword and its successor, the revolver.

What changes of a political, social and religious nature are to take place I do not know. One thing that the world is learning beyond doubt, is that individual effort, no matter how well developed the individual, is no longer a match for corporate effort. This is a lesson that the Frenchman and the Russian must be learning. We in the United States have learned it, but we hardly realize that we have learned it.

Let me try to explain what I mean. There are certain efforts that cannot be accomplished by the individual that require a combination of people such as was not contemplated at the time when our government was established. We can see plenty of examples in the mining industry and plenty more in the railroad business. In fact, we all know that the business of our country in general has reached a point where the large corporation is absolutely indispensable. Consider, for instance, the Utah Copper Company. Nothing but failure of such an undertaking could possibly have rewarded the efforts of any man or any group of men in this country 100 years, or even 20 years ago. Look at the organizations required to conduct the railroad business of this country. The railroads all started in a more or less individualistic manner. A little railroad was built from New York to Harlem; another from Harlem to Poughkeepsie; a third from Poughkeepsie to Albany; a dozen pieces of railroad were constructed to form a patchwork system of travel between New York and Chicago. The progress of our industry soon made it plain that such a system was absurdly less efficient than it might be; consequently these little roads were thrown into one system, and operated by one head, so that freight and passengers could be carried through with less expense and delay.

My belief is that the fundamental desire of the human race is to secure greater economy in the production of the necessities and luxuries of life. Any political system or any social idea which interferes with that economy will go to the wall, will be defeated and discarded. The demand for efficiency will finally triumph over any preconceived prejudices regarding personal and political liberty.

We were all born while a revolution was going on in human affairs, and we shall die before that revolution ends. This revolution is a fundamental accomplishment, such as the human race is not likely to repeat again for thousands of years. It is something that we are all familiar with, but which we do not think very much

*A paper read before the Mining and Metallurgical Society of America. In the informal introduction to his paper, which is published in full with the discussion that followed, in Bulletin 86 (Vol. 8, No. 7) of the Society, Mr. Finlay said: "I think the result of this war will be to arouse the entire world to the importance of the evolution through which we are going. We do not know the military situation in Europe. The nations do not give away their military secrets, but I had an idea last September that the outcome of the war could be predicted by a consideration of other than military factors. The ideas I intend to convey are, frankly, speculative, but after ten months of war it looks as if some of them were probably correct. I have formed one idea, the correctness of which remains to be proved, and I intend to call your attention to it."

about. It is the conquest of natural energy by the human brain.

One hundred and fifty years ago men had no resources for accomplishing their work except the muscular power of men and animals, with a little crude development of wind and water power. Now we use our hands and our brains to direct forces scores of times more energetic. The result is prodigious and it is causing a complete rearrangement of our mode of life. It is causing us to look upon nature itself in a different way, and it is altering profoundly the relations between men and between nations.

The source of this power at present is largely coal. The power of coal is developed through machines made of metals. This is not so much a chemical or material fact, as it is a human fact. The utilization of this power is made possible only by the development of human organizations to match it. A locomotive is no more the machine that accomplishes the work of a railroad than a statue is a living man. You cannot use a locomotive without a railroad, and you cannot have a railroad without work for it to do; you cannot have work for it without big industries. In short, you cannot have first-class mechanical service and efficiency except in a highly developed industrial nation. The mere existence of power-driven industry on a large scale proves in itself that a country which supports it possesses a different and more efficient organization than a country which does not support it.

When I learned some years ago that it took 10 to 15 Hindoo coolies to accomplish the work of one of our miners in this country, I could not understand it. The difference seemed preposterously great. It was all the more extraordinary because it occurred in a mine equipped with machinery just as thoroughly as the mines of this country. The reasoning I have offered you is an attempt to explain it. Industrial efficiency cannot exist in a population that neither understands nor demands it.

An adequate explanation must cover the improvements that are steadily made in our business. I know of mines in which each man is producing twice as much as he produced 10 years ago, without working any harder, and without any improvements in or additions to the machinery. I am satisfied that industrial efficiency means nothing less than national effort, produced by slow growth, by the habit of co-operation, and by a widespread recognition of the value of co-operation and a belief in its value.

It is a fact not generally recognized that to-day there are only three nations in which mechanical industry is widespread, namely, the United States, the British Empire, and Germany. It is not fair, of course, to say that industry has not been developed in other countries, but those nations are so far ahead of any rivals that they are very distinctly in a class by themselves. These three nations produce about 90 per cent of the coal of the world, and undoubtedly operate 90 per cent of its machinery. It is a remarkable fact—it may be an accident, but still it is a fact—that all of these nations are predominantly Teutonic. It may be an accident that this race of men happened to gain possession of the more important territories that contained coal; but whether an accident or not, it makes no difference as to the importance of the developments that have come from it.

It happens that one of these nations is the most highly developed military nation in the world. The other two, while developed industrially quite as highly as Germany, happen to be about the least military nations of the world. In my judgment, the unmilitariness of England and the United States is due to one cause only, namely, their isolation, their freedom from enemies capable of easily attacking them. If these nations felt compelled to do so, they could develop enormous military powers; but we may also believe, from our available sources of reasoning, that the development of such military power will take a long time and can be accomplished only by a thorough political and social organization on terms of military efficiency.

This is a long introduction to the concrete facts in Table I to which I now wish to call your attention.

Table I.—Comparison of Industrial Energy as Represented in Iron and Steel Plants of Russia, United States, and Germany

Russian Iron and Steel Plants, 1911.	
Number of plants	255
Workmen (Poland, 17,304)	263,653
Output of pig-iron, tons	3,943,000
Output of ready iron, tons	2,912,000
United States: U. S. Steel Corporation, 1910.	
Output of pig-iron, tons	11,831,000
Output of ready iron, tons	10,733,000
Employees manufacturing	154,563
Employees mining, coking, and transportation	60,000
Output per man:	
Russia: ready iron, tons	11
Pig-iron, tons	14
U. S. Steel Corporation, (total labor) ready iron, tons	50
Pig-iron, tons	55
Per manufacturer, ready iron, tons	70
Pig-iron, tons	76
United States: Rolling Mills and Blast Furnaces, 1909.	
Output of pig-iron, tons	25,600,000
Men employed	304,000
Output per man, tons	84
Germany: 1910.	
Metal workers of all ages	589,649
Output of pig-iron, tons	15,000,000

(If 400,000 are in ironworks, the output is 37 tons per man, about what we should expect by comparison with U. S.)

Data as to the production and consumption of fuels in the various countries are not so easy to procure without careful investigation. I take it that the main criterion of a nation's industrial activity is its consumption of coal, or any other form of mechanical energy, rather than its mere output. We shall have to make several tables to express what I mean.

Table II.—Production of Coal and Petroleum on the Continent of Europe and Elsewhere in 1912.

France:	
Production, tons	44,000,000
Imports, tons	19,000,000
Consumption, tons	63,000,000
Russia:	
Production of coal, tons	31,752,000
Imports of coal	Not given
Production of petroleum, tons	9,247,000

(If we assume that one ton of petroleum is equal in efficiency to 1.5 tons of coal, we might credit Russia with a total fuel consumption of about 45,000,000 tons.)

Belgium:	
Production, tons	25,322,000
Servia:	
Production, tons	335,000
Total production for this group, tons, about	115,000,000
Probable consumption, tons, about	135,000,000
British Isles:	
Production in Great Britain, tons	291,666,000
Exports, tons	95,536,000
Consumption, tons, about	196,000,000
Canada:	
Production, tons	15,000,000
Imports, tons, about	10,000,000
Consumption, tons	25,000,000
Australia:	
Production, tons	15,000,000
India:	
Production, tons	16,000,000
Total output of the British Empire, tons, approx.	338,000,000
Consumption of the British Empire, tons, approx.	225,000,000

Total industrial energy, represented by coal production among the Allies, not including Japan, at the beginning of the war, approximately 473,000,000 tons produced, and approximately 387,000,000 tons consumed.

Production of Germany and Austria-Hungary in 1912.

Germany:	
Production, tons	282,000,000
Net exports, tons	24,000,000
Consumption, tons	258,000,000
Austria-Hungary:	
Production of coal, tons	57,000,000
Imports of coal, tons	5,000,000
Production of petroleum, tons	1,000,000
(Equal to 1,500,000 tons of coal).	
Total production of Austria-Hungary, tons	63,000,000
Total output of Teutonic combination at the beginning of war, tons	340,000,000
Total consumption, tons	322,000,000

TABLE III.—RELATIVE PRODUCTION AVAILABLE WITHIN AND WITHOUT THE GERMAN LINES TO-DAY (USING FIGURES OF 1912)

For this purpose we will consider only the amounts consumed in the various countries, as representing their manufacturing energy.

Originally consumed in Germany and Austria-Hungary, tons	322,000,000
Add production of Belgium, tons	25,000,000
Add production of Northern France, tons	27,000,000
Add production of Western Poland, tons	6,000,000
Add production of Turkey, tons	1,000,000
Total manufacturing energy available, tons	381,000,000

The manufacturing energy probably available on the side of the Allies on the Continent, is as follows:

Russia, tons	40,000,000
France, tons	36,000,000
Italy, tons	12,000,000
Servia, tons	335,000
Total on the Continent, tons	88,335,000

The industrial energy of the British Empire remains about as it was, and is represented by approximately 250,000,000 tons of coal, which, however, is scattered all over the world. Thus it appears that while the Teutonic group began the war with a manufacturing energy equal to about four-fifths of that of all the Allies, excluding Italy, it now has a clear preponderance over the entire combination, including Italy.

We will similarly compare the situation with respect to the production of iron.

At the beginning of the war, Germany had a production, using as before the figures for 1912, of about 20,000,000 tons, to which she has added the production of Belgium, 2,500,000 tons and approximately 65 per cent of that of France, say, 3,500,000 tons, besides whatever may be produced in Poland; making a total manufacturing equipment available to-day of some 26 to 27 million long tons.

At the beginning of the war the Allies had the following production:

United Kingdom, tons	8,800,000
France, tons	5,000,000
Belgium, tons	2,500,000
Russia, tons	2,500,000
Canada, tons	1,000,000
Total, tons	19,800,000

At present the manufacturing ability of the group of Allies, as represented by pig iron, is probably not over 14,000,000 tons, even including Italy. Thus we see that at the beginning of the war the Germans possessed equipment for iron manufacture approximately equal to that of the Allies, but has now converted it into a preponderance of two to one.

It is interesting to know that the occupation of Belgium and Northern France deprived the Allies of industries consuming more than 50,000,000 tons of coal and producing more than 6,000,000 tons of pig iron a year. In the production of iron the facilities thus taken away from the Allies was equal to two-thirds of the entire production of Great Britain, and there is every reason to believe that this capacity was better adapted, on the whole, for the production of military supplies than the equipment in the British Isles.

The Germans have explained that their invasion of Belgium was a matter of military necessity. I have seen no statement as to what that military necessity was, but if this equipment is as important as we may now suppose it to be, we can make a pretty good guess. They probably felt that if they did not occupy this manufacturing district its output would certainly be used against them, if not by the actual military participation of Belgium, at least by furnishing munitions.

Some further interesting comparisons may be made. In the consumption of fuels, the United States is easily the foremost nation, consuming an average of over 5 tons per capita. England, Belgium and Germany seem to be about on the same level with the consumption of approximately 4 tons per capita.

It is, I believe, conceded by all observers that the industrial output per man is greater in the United States than in any other country; probably about in proportion to the consumption of coal, that is to say, the use of mechanical energy.

A review of the consumption of fuels by the leading industrial nations shows some interesting figures. Russia is apparently in about the same condition that the United States was in about 1850. Wood is still largely used as fuel for locomotives, just as it was in this country at that time. The consumption of mineral fuel is about ¼ ton per capita, as it was in the United States in 1850. In the progress of the United States from 1850 to 1914 we find that to-day we are using twenty times as much coal per capita as we were then; and an estimate of the wealth per capita, as given in the World's Almanac, shows $300 in 1850 and $1,350 in 1914. If the productivity of a nation can be measured by this wealth, it would seem that the producing capacity of an American citizen is at least four times that of a Russian.

It seems also that, by the same comparison, France is now only as far advanced industrially as the United States was about 1875. This certainly does not mean that specialized industries are not fully as well developed in France as in this country. What it probably does mean is that the mass energy is much less. France consumes only about 1.6 tons per capita, which I think almost certainly means that most of the French people are at work on farms and small shops and not in the factories. They work more with their hands and less with machinery.

The whole population within the German lines, excluding Turkey, is approximately 135,000,000; including Turkey, about 155,000,000. The average productivity of this whole mass of people, as measured in coal and iron, is about equal to that of the United States in the year 1890. Coal consumption is 2.5 tons per capita.

In white population the Allies stand about as follows:

British Empire	60,000,000
France	35,000,000
Italy	35,000,000
Servia	5,000,000
Russia	150,000,000
Total	285,000,000
Coal consumption, tons	340,000,000
Coal consumption, per capita, 1.2 tons.	

This average is equal to that of the United States at about 1870. Thus the Germanic combination is about twenty years ahead of the average of its opponents in the use of machinery. They draw their men and resources from a total area of 1,000,000 square miles, while their opponents come from the ends of the earth and dwell in an area of 10,000,000 to 15,000,000 square miles.

The newspapers and the public have arrived at the importance of these facts, so far as they apply to munitions of war. The cry is broadcast that the Allies must be supported by the manufacturing resources of England and the United States.

I return now to my original suggestion, that manufacturing power is only one-half of the problem. It seems likely that the organizing ability in Germany has attained a superiority over that of the Continental Allies in some proportion to her superiority in industrial activity.

To illustrate the situation in Europe, let us suppose that the States of the Union should get into war against one another. Suppose the States of Illinois, Indiana,

Michigan, Ohio, Pennsylvania, New York, Connecticut and New Jersey should form a combination to resist the rest of the United States, and Canada thrown in. Suppose for full measure we throw in Mexico and South America as opponents of this bit of territory. We would then have a population of 40,000,000 in a territory of 285,000 square miles fighting a population of 150,000,000 occupying a territory of 15,000,000 square miles. Which would be likely to win? I may be foolish, but it seems to me that the group of States between New York and Chicago would probably win decisively. Why? Because in that area, producing 75 per cent of the coal and making 87 per cent of the iron of the country, there is almost a monopoly of the organized manufacturing and engineering energy of the Western hemisphere. The area contains practically all the plants capable of manufacturing arms, munitions and special devices. In this territory we have not only the plants, but the trained population, the trained leaders and organizers. If we permit ourselves to imagine that this group of States were organized under one efficient corporation which had the control of every citizen for the purpose of carrying on war, we should have in America something like the situation in Germany to-day. We could well reject the idea that the New Yorker or the Pennsylvanian was in the least superior to the Canadian or the Texan, but that would not alter the fact that the superiority of our group of States in the production of munitions, the transportation of supplies, the organization of effective effort, and its ability to strike quickly, would be very great indeed. If this group of States should make as its first move the occupation of West Virginia and of Missouri, it would add to its preponderance much as the Germans have added to theirs by the occupation of Belgium and Poland.

If, in addition to the enemies we were fighting in America, Great Britain should come in and use her command of the seas to help our neighbors out with supplies, what would be the result? I do not believe that it would be decisive. I still think that the problem of conquering such a unit would be insoluble. We might not be able to make extensive conquests, nor wrest the command of the seas from the English, but we could meet any probable attack with such a wall of mechanical energy that we could make expectant conquerors sick with hopes deferred.

War Consumption of Metals

In the discussion which followed Mr. W. R. Ingalls discussed the extraordinary consumption of metals by the war which is much greater than had been anticipated by experts. At the beginning of the war the consumption of copper by the Allies was estimated as 100,000 metric tons a year; independently the consumption by the Germans was also estimated as 100,000 metric tons a year. Both estimates are conservative and probably too low. Considering that the world's largest production in any year was about 1,000,000 metric tons, we begin to have a better perspective of the military demand.

"Most of the copper is used in the form of brass, which, of course, requires a corresponding proportion of spelter. In purchasing the spelter for this brass an extraordinary effect upon the market was produced. Ordinary brands of spelter rose to about 500 per cent of normal value, while high-grade spelter realized prices approaching the price of tin in ordinary times. Attention was chiefly centered on the special brands of spelter produced by the New Jersey Zinc Company. This is a metal in a class by itself, containing upward of 99.9 per cent zinc, and being free from undesirable impurities to an extent that is unmatched by any other spelter. This spelter is sold as the Bertha and Horsehead brands. Before the war such spelter had a rather limited use for special purposes. Inventors and promoters were always going to duplicate it, and in prospectuses they were always going to get the 2 cent or 3 cent premiums that these brands normally realized above the price for prime western. Those of us who knew something of conditions warned all of our friends who wanted to go into such enterprises that the addition of any important supply of this kind of metal, even if it could be produced, would break the margin, and in figuring upon a new zinc-smelting enterprise it was never safe to reckon on anything higher than the price for prime western, or good ordinary brands. Recent events have been directly contrary to our *antebellum* opinion and advice. We have seen it impossible for buyers to obtain all of the high-grade spelter they wanted, whence the premium for such spelter rose phenomenally. Almost anything that the New Jersey Zinc Company wanted to ask it could get. Other smelters were left to make a spelter by redistillation, almost, but not quite, as good. Impure spelter may be refined into pure spelter by redistillation, just as pure water may be obtained from brine, but there is difficulty with respect to the cadmium content, which is volatile, like zinc, and perhaps some difficulty with respect to lead also; wherefore it appears to have been impossible to raise the spelter redistilled from prime western above 99.75 to 99.85 per cent of zinc, which makes it a high-class intermediate spelter, rather than high-grade spelter properly speaking, according to the official classification. However, such spelter has been greatly in demand and has commanded very high prices.

"Now just why the military buying has been so insistent upon these superior brands is something of a mystery to me. Of course, I know that such spelter has always been required for the manufacture of cartridge cases, and there are good reasons why it should be, but apparently manufacturers who have been going to make ammunition of other kinds than cartridge cases have also insisted upon such spelter. I have wondered whether the military experts have not, in some cases, specified a purity that is not really necessary, having in mind only the idea of obtaining the very best. I have not heard that the German military authorities have exhibited any such crazy demands for high-grade spelter. What have they been doing for their supply of it? Other things are curious. Why should it have been necessary to produce a condition of spelter selling for £110 per ton in London, while it is selling for £29 in Germany in 1000-ton lots?

"Lately we have witnessed, also, a spectacular demand for lead. This metal is used for the cartridge bullets, for the shrapnel balls, etc.

"Other metals have experienced similar advances, which non-military persons did not foresee. Antimony is one of them. This is used for hardening the lead for the several bullets. Quicksilver is used in making the fulminates which go into the caps. The quicksilver market has been especially disturbed since Italy entered the war and thus cut off the supplies that we were heretofore able to draw from it. Aluminium is used largely in the construction of aeroplanes and dirigibles. There are rarer metals which also have had sensational advances. Such a one is magnesium, which doubtless is required for making the illuminating bombs, flares, etc., used in night attacks."

Mr. G. C. Stone (N. J. Zinc. Co.) explained that cartridge brass has to stand the severest strains in drawing presses and the zinc should be free from cadmium and contain not over 0.05 per cent lead and 0.15 per cent iron.

Condensers for Evaporating Apparatus

Principles, Types, Tests

In our August issue we gave an extensive account of the chapter on vacuum pans from the recent publication of Professor **E. W. Kerr,** assisted by J. F. Gunther and W. A. Rolston, on Sugar House Heating and Evaporating Apparatus (Louisiana Bulletin No. 149, Agricultural Experiment Station of the Lousiana State University and A. & M. College, Baton Rouge, La.). This same bulletin contains a very interesting chapter on sugar-house condensers from which we take the following extracts. Professor Kerr first considers the general principles of condensers for evaporating apparatus, then describes different types of condensers and finally gives the results of tests made by him.

General Principles of Condensers for Evaporating Apparatus

As a general thing, 26 in. of vacuum referred to a barometer of 30 in. is sufficient for vacuum pans and evaporators of the submerged tube type.

Film evaporators can use higher vacuum to advantage because there is no loss of temperature fall in them due to hydrostatic head. The loss due to hydrostatic head is much greater in the last body of a multiple effect than in a first body, and for this reason a high vacuum in the submerged tube types does not result in the increase of capacity that is possible in film evaporators.

High vacuum is also more desirable in triple and quadruple effects, especially of the film type, than in double effects. The rate of evaporation per square foot of heating surface per hour must be limited in order to prevent entrainment. With a given total temperature fall a double effect will naturally have greater temperature falls in each body than in triples or quadruples, resulting in higher rates of evaporation. For this reason the increased total temperature fall due to increasing the vacuum or the steam pressure is less likely to cause entrainment in triples and quadruples than in doubles.

The cost of high vacuum, 27 or 28 in., is greater than for ordinary amounts of vacuum for several reasons, among which may be mentioned more cooling water, more vacuum pump capacity, greater attention to providing against leakage from stuffing boxes, etc., larger vapor pipes and larger condensers. Most sugar-house condensers are of the barometric jet type, in which the vapors mix directly with the cooling water, being condensed and cooled down to the temperature of the water leaving the condenser. The cooling water required per pound of vapor condensed can be calculated by means of the formula:

$$W = \frac{H - (t_2 - 32)}{t_2 - t_1},$$

in which H is the total heat of steam at the pressure corresponding to the vacuum, t_1 is the initial temperature of the cooling water and t_2 the final temperature of the cooling water. Increasing the vacuum will naturally increase the value of t_2, which in turn will result in increasing the weight of cooling water per pound of vapor condensed.

This increased amount of cooling water means larger and more costly cooling water pumps, also increased steam consumption, wear and tear. Table I shows the increased amount of cooling water required with high vacuum.

The values in Table I were calculated according to the above formula, the final temperature of the cooling water being assumed to be 5 deg. lower than that corresponding to the vacuum.

Inspection of the above formula shows that in order to secure a given vacuum with the least amount of cooling water the value of t_2—that is, the leg pipe temperature—must be a maximum. In other words, the condenser must be the main factor in forming vacuum and not the vacuum pump, the object of the latter being to remove air and not vapors.

TABLE I—COOLING WATER AND VACUUM

Vacuum	Cooling Water Per Lb. Vapor, Lbs.
24.0	18.8
24.5	20.0
25.0	21.3
25.5	23.2
26.0	26.4
26.5	29.4
27.0	35.6

The pressure in a condenser is the air pressure plus the vapor pressure. According to Dalton's law, "The pressure of a mixture of a gas and a vapor is the same as the sum of the pressures each would possess if it occupied the same space alone."

In a vessel containing vapor only, with a vacuum of 27.99 in. of mercury, the temperature is 100 deg. F. In case there is some air mixed with the vapor, however, the pressure (1.926 in. of mercury) would be the sum of the pressures due to the air and to the vapor, and the pressure due to the vapor would be something less than 1.926 in., and the temperature in the vessel would correspond to this lower pressure. From this it is evident that the less air there is in a condenser, the nearer will the temperature approach that corresponding to its pressure, as given in steam tables.

Even in the best of condensers, the temperature of the discharge water (hot well) is lower than that corresponding to the vacuum. This is due to the presence of air with the vapor and a vapor pressure less than that shown by the gage, the temperature being due to the vapor pressure. If it were possible to exclude the air entirely, the temperature would be that due to the pressure shown by the gage. This would result beneficially in increasing the temperature of the hot well, and this in turn would decrease the weight of cooling water required to condense a pound of steam.

When pure steam in a condenser is cooled by contact with air-free water the original volume occupied by the steam and water is greatly reduced. For example, assume that one pound of steam under a pressure corresponding to 26 in. of mercury requires 30 lb. of water at 70 deg. F. to condense it. The volume of the steam is 175 cu. ft. and that of the water about ½ cu. ft., a total of 175½ cu. ft. Upon condensing, the volume of 1 lb. of steam becomes 1/60 of a cu. ft., so that the final volume of the mixture will be $\frac{1}{2} + 1/60 = 0.5016$ cu. ft. Thus, the volume is reduced from 175.5 cu. ft. to 0.5016 cu. ft. by perfect condensation, and the resulting void would give practically a perfect vacuum.

However, in actual condensing apparatus the above conditions are not fully carried out for the reason that there is air both in the steam and in the cooling water entering the condenser. In addition to the air in the condensing chamber, which decreases the vacuum—that is, increases the absolute pressure—there is also vapor from the warm water, the pressure of which depends upon the temperature of the water. Even if there were no air in the condensing chamber this vapor would be present. The figures in Table II taken from a steam table show the water vapor pressures for varying temperatures under vacuum.

Column 3 of Table II is obtained by subtracting the vapor pressure, column 2, from the pressure of the atmosphere which is assumed to be 29.92 in. mercury. The values in this table apply to water vapor only. If

it were practicable, a removal of the vapor formed, as explained above, could be resorted to for the purpose of increasing the vacuum. By thus removing vapor from the condenser with a pump, other fresh vapor would be formed from the water in the condenser to take the place of that removed and the absorption of heat required for this would cool the water and this in turn would result in an increase of vacuum.

TABLE II—WATER VAPOR PRESSURES FOR VARYING TEMPERATURES UNDER VACUUM

Temp. of Water, Degrees F.	Vapor Pressure, Inches Mercury	Vacuum Inches Mercury
32	.1804	29.7396
40	.2477	29.6723
50	.3625	29.5575
60	.5220	29.398
70	.739	29.181
80	1.029	28.891
90	1.417	28.503
100	1.926	28.994
110	2.589	27.331
120	3.438	26.482
126	4.057	25.863
134	5.02	24.90
152	7.95	21.97
162	10.12	19.80
170	12.20	17.72
182	15.98	13.94
190	19.02	10.90
200	23.47	6.45
212	29.92	0.00

Owing to the great volume of this vapor, however, a pump sufficiently large for this purpose would be impossible, as is shown in the following example. Assuming a condenser which requires 30 lb. of water to condense 1 lb. of steam and that the water is heated in the condenser to a temperature of 126 deg. F., corresponding to a vacuum of 26 in., let us determine the volume of vapor that must be removed by a pump in order to reduce the temperature to, say, 116 deg.—that is, to reduce the temperature 10 deg.

For each pound of steam to be condensed there would be required 10 x 30 = 300 B.t.u. to cool the water 10 deg. The latent heat of evaporization of water at 26 in. being 1026 B.t.u. $\frac{300}{1026} = 0.292$ lb. vapor would be formed, and, therefore, removed by the pump in order to cool the water 10 deg. One pound of the vapor at this temperature has a volume of 175 cu. ft. Therefore, 175 x 0.292 = 51 cu. ft. of vapor would have to be removed for each pound of steam entering the condenser. An evaporator with 5000 sq. ft. of heating surface in the last body would deliver, say, 30,000 lb. of vapor to the condenser per hour, or 500 lb. per minute. The pump displacement of vapor to reduce the temperature 10 deg. would, therefore, be 51 x 500 = 25,500 cu. ft. per minute. The vacuum corresponding to 116 deg. is 27 in.; 25,500 cu. ft. of vapor would thus have to be removed per minute to increase the vacuum only 1 in. This would require a pump with dimensions entirely without the limits of practicability.

Larger vapor pipes are required with high vacuum because the specific volume of vapors—that is, the volume in cubic feet—occupied by 1 lb. of vapor increases rapidly as the vacuum increases. For example: the specific volume of vapor at 26 in. of vacuum is 175 cu. ft., for 28 in., 330 cu. ft., and for 29 in., 638 cu. ft. Thus the area of vapor pipes for 28 in. vacuum needs to be nearly twice that for 26 in. vacuum. The work to be done by condensers for evaporators depends upon the number of bodies. A condenser for a quadruple effect would have to handle about half the vapors that one for a double of the same capacity would have to handle.

Types of Condensers

Condensers of the kind used in sugar-house work are nearly all of the barometric type—that is, the vapor and the water mix in direct contact. The mixture of condensed vapors and cooling water passes to the hot well through the leg pipes by gravity, the condenser being located some 34 ft. or more above the surface of the water in the hot well. These condensers require injection water pumps for elevating the water to the condensers; also, in most cases, vacuum pumps of the rotary dry type, or of the slow speed water sealed type.

Generally a sugar house condenser consists essentially of a tall cylindrical vessel into which the vapors and the cooling water are led and mixed. The water enters at the top and is sprayed as it falls and mixes with the vapors. These condensers, according to the manner in which the steam is introduced, may be classified as parallel-current and counter-current; in parallel-current condensers the vapor enters the top, the cooling water and the vapors flowing in parallel currents at the bottom and out through the leg pipe; in counter-

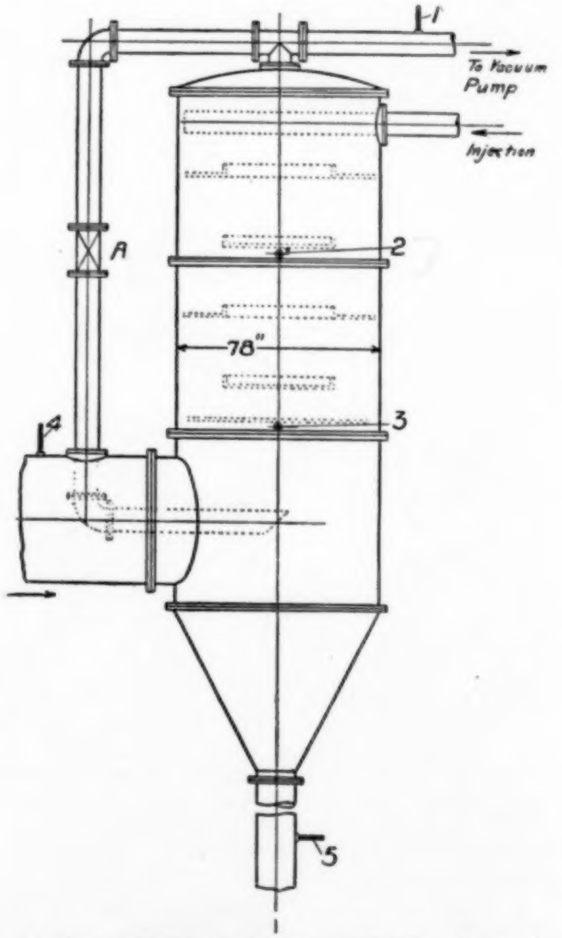


FIG. 1—COUNTER-CURRENT CONDENSER (TYPE I)

current condensers the vapors enter at the bottom and pass upward, their direction of movement being counter to that of the cooling water, hence the term counter-current.

Fig. 1 illustrates a counter-current condenser upon which Professor Kerr made tests. Fig. 2 illustrates a parallel-current condenser which was also used in some of the tests. Referring to Fig. 2, it will be noted that the injection water enters the top, being controlled by a valve accessible to the operator. The water is sprayed and falls to one and then to another of two trays of semi-circular shape and finally to the bottom of the condenser and down the leg pipe. The trays are perforated with small holes, which cause a shower of water throughout the condenser. Vapors enter through the large pipe at the top and pass down-

ward. The air and other incondensable gases are swept toward the bottom, from there they are removed by the vacuum pump through the pipe shown, a conical thimble being placed so as to prevent water from entering the air pipe. The edges of the trays are serrated in saw-tooth form to aid in dividing the overflow water into as finely divided a condition as possible, to facilitate an intimate mixture of water and vapor.

In the counter-current condenser of Fig. 1 the injection water pipe extends across the top and is perforated with small holes, thus spraying the water which falls from one to another of four circular trays with perforations and serrated edges. The vapors enter through the large pipe at the bottom and pass to the top, the air and other incondensable gases being drawn off by the vacuum pump through the connection shown. The

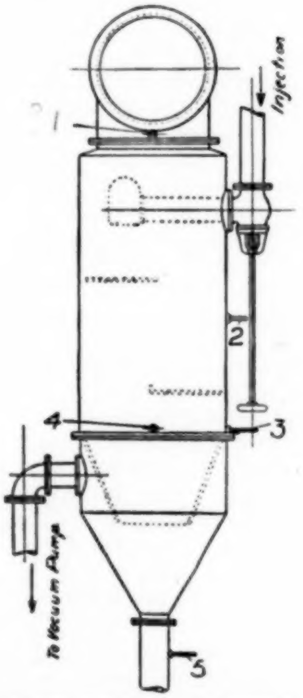


FIG. 2—PARALLEL-CURRENT CONDENSER (TYPE II)

valve A and its connecting pipe was put in for experimental purposes and was not a part of the original installation.

In the parallel-current condenser, Fig. 2, it will be noted that the air is drawn off near the bottom of the condenser, where the temperature is practically that of the leg pipe—that is, of the cooling water as it leaves. In Fig. 1, however, the air is drawn off from the top of the condenser just after having passed through the spray of cool injection water, and its temperature should be practically that of the entering injection. This is an advantage in that the vacuum pump will have a smaller volume of air to handle on account of its lower temperature. In other words, counter-current condensers should require a smaller vacuum pump displacement for a given amount of air handled than a parallel-current condenser on account of the reduced temperature. This difference in volume may amount to 10 per cent or more. An important consideration in condensers is that of the separation of vapors from incondensable gases so that the latter only will have to be handled by the vacuum pump. In this also the counter-current condenser seems to have the advantage.

Referring again to Fig. 1, it is evident that as the mixture of air and vapor move upward through the spray of cooling water, more and more of the vapor will be condensed, so that by the time the top is reached only air will be left, the injection with lowest temperature making it least possible for vapors to reach the air pump. On the other hand, with the parallel-current condenser, Fig. 2, the temperature of the water near the air discharge being relatively high, there is greater possibility of a mixture of vapor and air being drawn off by the air pump.

In any condenser the lowest pressure is at the coolest point, which is at the top in both the counter-current and the parallel-current types. In the counter-current condenser the air pipe is, therefore, at the point of least pressure, and the air should naturally move in that direction. In the parallel-current condenser, however, the air is taken off at the point of highest temperature, and, therefore, the highest pressure, a condition which does not facilitate separation of air from vapor. On account of the great specific volume of vapors under vacuum it is evidently of great importance to avoid handling vapors with the air pump.

In securing a good separation of vapors from air the size of the condenser plays an important part—in other words, the diameter of the condenser must be large in order to prevent excessive vapor velocities in it. If the velocity of the vapors is too high, there will not be sufficient time for complete admixture of water spray and vapors, and this will result in incomplete condensing

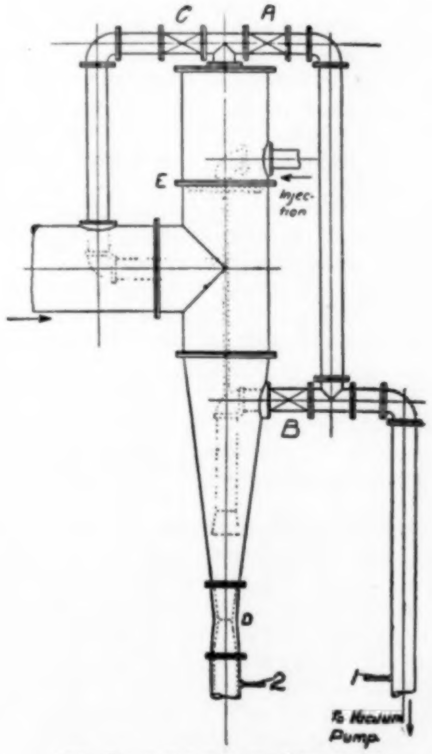


FIG. 3—CONDENSER (TYPE III)

of the vapors; in fact, the size has much to do with the results obtained from either parallel-current or counter-current condensers.

MIXING DEVICES

Attention has already been called to the use of trays having perforated bottoms and serrated edges, these trays being placed one above the other. In some cases only one tray is used, this being placed near the top, giving an uninterrupted shower from top to bottom. The latter would naturally give less time for contact of water and vapor, though it has the advantage of a

smoother flow of vapor through the condenser and a smaller velocity of the vapors. The trays naturally reduce the area of passage.

SUGAR HOUSE CONDENSERS WITHOUT VACUUM PUMPS

Fig. 3 illustrates a type of condenser in which the vacuum pump is often dispensed with. This condenser, as will be seen, is of the parallel-current type without trays, the original installation being that part below the flange *E*. The portion above *E*, including the valves *C* and *A* and their connecting pipes, were installed for experimental purposes. The vacuum pump connection belongs to the original installation, this being required for starting. Under normal operating conditions, however, the vacuum pump may be dispensed with, the air entering the condenser being entrained by the water passing through the restricted throat *D*. Even though the vacuum pump is used, its work is at least reduced by the aspirator *D*.

Tests of Condensers

With these different types of condensers Professor Kerr carried out a number of systematic tests. The condensers tested were of full size and used in the regular operation of evaporators or vacuum pans in sugar plants.

The object of the tests was to obtain especially first-hand information on the relative merits of the counter-current and parallel-current condenser types. In view of the fact that the advantages claimed for counter-current condensers are based on differences in temperature and pressure relation in the two types, the conditions of temperature and pressure were determined at different locations in the different types. Since the weight of cooling water required to condense a pound of vapor is an important consideration, attention was also given to this.

Tables III, IV, V give temperature observations from condenser types A, B, C respectively (Figs. 1, 2, 3). In each case thermometers were placed at points 1, 2, 3, etc., the observed temperatures being numbered to correspond in the tables. In all tests the temperature of the injection was constant and about 80 deg. Fahr.

TABLE III—OBSERVATIONS ON CONDENSER TYPE I (FIG. 1)

Time	Temperature at					Vacuum, In. Mercury	Temp. Due to Vacuum, Kestner 6	Temp. Dif. 6–5	Conditions
	1	2	3	4	5				
1:45	122	83	132	134	113	25.5	130.0	17.0	Valve A open.
2:00	124	83	132	134	112	25.5	130.0	18	Valve A open.
2:20	125	83	134	136	114	24.5	137.8	23.8	Valve A open.
2:40	'24	82	139	140	113	24.5	137.8	24.8	Valve A open.
3:00	106	83	132	134	112	25.25	132.0	20.0	Valve A closed.
3:20	99	83	140	142	115	24.0	140.8	25.8	Valve A closed.
3:40	96	81	134	137	113	24.5	137.8	24.8	Valve A closed.
4:00	95	81	132	131	114	25.25	132.0	18.0	Valve A closed.
4:20	89	82	134	135	114	25.0	133.8	19.8	Valve A closed.
4:40	86	82	136	136	125	24.7	136.0	11.0	Valve A closed.
4:55	86	83	137	137	131	24.5	137.8	6.8	Valve A closed.
5:15	86	81.5	140	142	118	23.9	141.0	23.0	Valve A open 3 turns.

The observations given in Table III were made on a counter-current condenser. The arrangement of trays was somewhat different from that of the original installation, a plate just above thermometer No. 3 having been substituted for an annular tray like the top tray. The plate is of brass with perforations and its diameter only 6 in. less than the inside diameter of the condenser shell.

This substitution was made with the hope of improving the condenser. After the change, however, it was noticed that the condenser did not work smoothly, there being considerable vibration and noise attended with rapid fluctuation of the vacuum as shown by the mercury column vacuum gage. The conditions given in Table III were found with the condenser thus changed.

It will be noted that the temperature at 2 was only slightly greater than the initial temperature of injection. The thermometer must have been directly under a shower of water which, being out of the vapor path, had not been heated to any extent.

The readings from thermometer No. 1 in the suction pipe of the vacuum pump show interesting information. The first four readings were taken with the valve A open, establishing a direct connection between the hot vapor space at the bottom and the vacuum pump. With

TABLE IV—OBSERVATION ON CONDENSER TYPE II (FIG. 2)

Time	Temperature at					Vacuum in Pan, In. Mercury	Temp. Due to Vacuum 6	Temp. Difference 6–5
	1	2	3	4	5			
10:40	130	129	......	114	109.4	25.5	130	20.6
10:50	130	125	......	114	98.6	24.5	137.8	39.2
						24.5		
11:00	130	130	108	...	104	25.3	132.0	28.0
11:10	126	126	108	111	105.8	26.1	134.5	28.7
11:20	135	124	105	106	167.2	26.4	121.0	13.8
11:30	137	129	107.3	110	105.8	26.2	124.5	18.7
11:40	137	128	107	108	104	26.2	124.5	20.5
11:50	136	128	107	108	105	26.2	124.5	19.5
12:00	137	123	107	106	100.8	26.4	121	20.2
12:10	136	124	108	107	104	26.3	122.5	18.5
12:20	136	127	110	108	106.4	25.8	127.0	20.6
12:30	132	131	116	112	107.6	25.4	131.0	23.4
12:40	124	124	107	104	103.4	26.1	129.0	25.6

TABLE V—OBSERVATIONS ON CONDENSER TYPE III (FIG. 3)

Temperature at 1 Pump	Temperature at 2 Leg	Vacuum in Mercury	Temperature Due to Vacuum 3	Temperature Difference 3–2	Injection per Lb. Vapor, Lbs.	Conditions
126	122	24.6	137	15	25.1	Valve A closed. Valve B wide open.
124	117	24.6	137	20	28.7	Valves same. Injection increased.
115	107	24.7	136	29	40.1	Valves same. Injection increased.
121	117	24.6	137	20	28.7	A open 3 turns. Injection as at first.
118	114	24.7	136	22	31.4	A open 4 turns. Injection same.
118	114	24.5	137.5	23.5	31.4	A open 5 turns. Injection same.
118	115	24.5	137.5	22.5	30.5	Injection same. A wide open. B wide open.
119	116	24.8	135	19	29.2	Injection same. A same. B closed 3 turns.
118	114	24.7	136	22	31.4	Injection same. A same. B closed
121	115	25.0	134	19	30.4	Injection same. A same. B closed 9 turns.
114	111	24.4	138	27	24.7	Injection same. A open. B closed.

this condition the temperatures in the vapor pipe were some 8 to 12 deg. lower than the temperature corresponding to the vacuum. These relatively high temperatures indicate that the vacuum pump was drawing over a large amount of vapors. It will be noted also that those temperatures were considerably higher than the leg pipe temperature taken at the same time.

The last eight readings were taken with the valve closed and the temperatures observed may be assumed to show the conditions that may be expected with the normal operation of counter-current condensers. Here it will be noted that the temperatures at thermometer No. 1 ranged from 86 to 99, though the former probably comes nearest normal, the higher temperatures having been obtained immediately after closing valve A. These temperatures are some 40 to 50 deg. lower than the temperatures corresponding to the vacuum and very slightly above the temperature of injection, indicating air with very little vapor mixed with it.

Thermometers 3 and 4 show temperatures practically the same as that corresponding to the vacuum, the former being slightly lower than the latter, which is to be expected.

The average reading at 4 is slightly higher than that corresponding to the vacuum. This may be due to an error in the barometer reading, which was assumed to

be 30 in. This, however, will not affect the general value of the observations given in the table.

The temperature difference given in the last column of figures is the excess of the temperature corresponding to the vacuum over the leg pipe temperature. It varies from a maximum of 25.8 to a minimum of 6.8 deg., the latter figure having been obtained by a considerable reduction in the amount of injection water used. As stated above, most of the observations were obtained with an amount of injection water considerably in excess of that required by the condenser for the vacuum maintained.

These observations were taken while the condenser was handling the vapors from a quadruple effect, which was handling juice at the rate of about 400,000 gal. per 24 hr. The valve *A* and its connecting pipe was installed to ascertain if such a connection would do away with the vibration and noise caused by the substitution of the brass plate at the bottom, which has been mentioned. In subsequent tests of this condenser it was found that it could be operated with much less injection water than was used when these observations were made without reducing the vacuum. Further observations relative to this will be given later.

The observations given in Table IV were made on condenser Type II, Fig. 2, which is of the parallel-current type. This condenser serves a 12-ft. coil vacuum pan. At the time the observations were made a mixed strike with corresponding low purity was being boiled. Here we have greatly varying temperatures showing a considerable irregularity of conditions in different portions of the condenser. It will be noted that thermometers 3 and 4 show average temperatures only slightly greater than in the leg pipe shown by thermometer 5. Both thermometers 3 and 4 were doubtless affected by a flow of water over them, though the latter was in a current of vapor.

The relations of the temperatures found at 1 to the temperatures corresponding to the vacuum are somewhat irregular. This is probably due to rapid fluctuations of the vacuum causing a change in the one to be shown before the change has affected the other. The temperature in the suction pipe of the vacuum pump was not observed, though it was probably somewhere between the temperatures at 4 and 5—that is, in the neighborhood of 108 deg., a temperature much higher than that obtained with the counter-current condenser as shown by thermometer 1 in the latter part of table III. This high temperature indicates the presence of much vapor along with the gases. The excess of the temperature due to the vacuum over the leg pipe temperature varies from 13.8 deg. to 39.2 deg., the average being 22.8 deg. During most of the time the injection water valve was about as close as it was possible to have it without decreasing the vacuum.

Table V gives the results of observations on condenser Type III, Fig. 3. By means of the valves A and B and connection pipes it was possible to operate this condenser either counter-current or parallel-current—that is, with B closed and A open it operated counter-current and with B open and A closed it worked parallel-current. In the tests recorded in Table V the condenser was operated both ways, also while gradually changing from one condition to the other. The condenser was connected to the vacuum pump in all cases, though as heretofore explained the aspirator D did service in removing a portion of the incondensable gases.

In these observations only two temperature readings were obtained, namely, in the leg pipe and in the air pipe to the vacuum pump. The first three readings were taken while operating parallel-current, the injection being varied. It will be noted that the temperature in the leg pipe varied from 15 to 29 deg. ~~above~~ the temperature corresponding to the vacuum. The temperature in the air pipe for these three readings varied in the opposite direction with an average of about 120 deg., indicating a considerable quantity of vapors mixed with the air. The last three or four readings were taken with the condenser operating practically counter-current. In general there seems to be little difference in the results as regards temperatures when worked counter-current or parallel-current.

Pressure Relations

In comparing parallel-current and counter-current condensers it was stated that as a parallel-current condenser is hotter at the bottom than at the top, theoretically the pressure should be lower at the top—in other words, the pressure would vary at different points in condensers of either type. In order to ascertain if this difference of pressures actually existed, pressure observations were made in several different condensers.

In one counter-current condenser 5 ft. in diameter, serving a quadruple effect which delivered about 230 lb. of vapor to the condenser per minute, it was found that the pressure at the top was exactly the same as at the bottom. The comparison of pressures was made by means of a mercury manometer, one side of which was connected to the lower end of the condenser, and the other side to the top of the condenser, holes having been tapped into the bottom and top for the connection.

Another counter-current condenser 4 ft. in diameter serving a double effect and condensing about 180 lb. of vapor per minute gave a reading of 23.95 in. vacuum at the top and 22.5 in. at the bottom; that is, the vacuum at the top was 1.45 in. greater than at the bottom. This condenser had only one spray plate at the top, the water below it having an uninterrupted fall to the bottom.

A parallel-current condenser, with trays arranged practically as in Fig. 2 and handling vapors at the rate of about 110 lb. per minute, shows the same vacuum at the bottom as at the top, the vacuum being 22.46 in.

A parallel-current condenser, with three trays 2 ft. apart arranged as in Fig. 2, serving an 8-ft. vacuum pan, showed $\frac{3}{4}$ in. greater vacuum at the bottom at one time with three coils on and $1\frac{1}{4}$ in. greater vacuum at the bottom later with five coils on. The diameter of the condenser was 42 in. and it was condensing vapors at the rate of about 170 lb. per minute with a vacuum of 26 in.

At first sight it would appear that the results of these observations were quite contradictory. On investigation, however, it will be seen that the two condensers which have different vacuums at the top and bottom were relatively small and were handling larger volumes of vapor than in the case of the other two. It will be noted, also, that the higher vacuum in the parallel-current condenser was at the bottom, whereas in the counter-current condenser the higher vacuum was at the top. This seems reasonable as regards the counter-current condenser, though why there should be a higher pressure at the bottom of a parallel-current condenser is not so apparent, unless it be due to the pull of the vacuum pump.

Attention has already been called to the substitution of a plate instead of the original bottom tray in Fig. 1. It has been stated, also, that after this change there was considerable noise and vibration. After full consideration, it was thought that this might be due to a surging of vapors back and forth above and below this plate. On one occasion it was noted that there were twelve fluctuations at the vacuum gage of 1 in. every five minutes, the upward movement being much quicker

than the downward movement, the noise and vibration occurring at the beginning of the upward movement of the vacuum gage. The vacuum gage, which was of the mercury-column type, was connected to the space below the plate.

In order to get some data regarding this a mercury manometer was rigged up and one side connected to the space above the plate and the other side to the space below the plate. Upon operating the condenser again it was found that the mercury would vary, being first higher in one leg of the manometer and then suddenly reversing, showing that there was actual reversal of pressures in the condenser above and below the plate. This would naturally react upon the last body of the evaporator itself and cause unsteady action thereof.

It may be well to state here that the noise and vibrations spoken of usually occurred when the supply of injection water was reduced to a point where the leg pipe temperature was very near that of the temperature due to the vacuum. After the fact of these pressures reversals was established the plate was gradually reduced in diameter from time to time until a space of 9 in. was left between the plate and the shell, at which point the vibration ceased and the condenser worked smoothly.

All of the pressure observations seem to be of value mainly in pointing out the desirability of liberal size and careful designing of trays, both as to size and location, in order to secure steady action and the prevention of pockets.

Quantity of Injection Water

The unit assumed for measuring injection water is, "pounds of injection water per pound of vapor condensed." The point has already been brought out that for a given absolute pressure in the condenser the amount of cooling water depends mainly upon the amount of air or other incondensable gases mixed with the gases in the condenser. The presence of air results in a higher leg-pipe temperature than there would be if no air were present. Theoretically, the greater the amount of cooling water the greater the vacuum due to the cooling effect. Actually, however, there is a limit to this because the water brings in air with it which offsets the reduction in pressure due to cooling. This is especially so in condensers with a poor separation of air from vapor. The weight of cooling water per pound of vapor has to be calculated from temperature and vacuum data, as it is not practicable to actually weigh the water; however, the calculated values are quite accurate.

Tables III and IV give data bearing upon the weight of cooling water per pound of vapor, though indirectly. Other conditions being the same, the weight of cooling water per pound of vapor is almost proportional to the difference between the temperature corresponding to the vacuum and the leg-pipe temperature. It will be noted that in Table III this value varies from a minimum of 6.8 deg. to a maximum of 25.8 deg—that is, the maximum is nearly four times the minimum. It will be noted, also, that the vacuum was less with a large temperature difference than with a small temperature difference. These observations were made on a counter-current condenser handling in the neighborhood of 550 lb. of vapor per minute. The minimum difference shows something of what can be done with careful manipulation of the injection water.

Table IV, giving the observations on a parallel-current condenser serving a vacuum pan, shows a minimum difference of 13.8 deg. and a maximum of 39.2 deg. The temperature difference in all cases is much higher than is considered good in practice. A minimum difference of 13.8 deg. is probably about the best that could be done with this condenser. It will be noted, also, that this was obtained with the highest vacuum observed in the series.

Table V gives values of injection per pound of vapor varying from 24.7 to 31.4 lb. The temperature difference is in all cases very high.

Table VI—Observations on Condenser Type IV

Vacuum	Temp. Due to Vacuum	Temp. Leg Pipe	Temp. Difference	Injection Water per Lb. of Vapor, Lbs.	Conditions
24.5	137.5	120	17.5	26.5	
24.5	137.5	120	17.5	26.5	Injection valve open an additional turn
24.6	137	119	18.0	27.2	Same.
24.65	136.5	116.5	20.0	29.2	Same.
24.5	137.5	120	17.5	26.5	As at first.
24.25	139	124	15.0	23.8	Injection valve closed one turn.
23.8	142	127	15.0	22.3	Injection valve closed two turns.

Note.—In no case could the injection valve be altered without affecting the vacuum. Type IV condenser is the same as that part of Type III condenser below flange E.

Table VII—Observations on Condenser Type V

Vacuum	Temp. Due to Vacuum	Temp. Leg Pipe	Temp. Difference	Injection Water per Lb. of Vapor, Lbs.	Conditions
25.0	134	118	16.0	28.2	
24.9	134	120	14.0	26.4	Injection valve closed one turn.
24.8	135	123	12.0	24.4	Injection valve closed 2 turns.
24.65	136.5	126	10.5	22.8	Injection valve closed 2½ turns.
24.5	137.5	130	7.5	20.8	Injection valve closed 3 turns.

Note.—In no case could the injection valve be altered without affecting the vacuum. Type V condenser is the same as that part of Type III condenser below flange E.

Table VIII—Observations on Condenser Type I

Vacuum	Temp. Due to Vacuum	Temp. Leg Pipe	Temp. Difference	Injection Water per Lb. of Vapor, Lbs.	Remarks
25.5	130	130	0	20.8	
26.5	121	120	1	26.2	
25.75	128	125	3	23.2	
26.25	123	120	3	26.5	
25.5	130	130	0	20.8	
24.8	135	130.3	5.2	19.9	Average during evaporation test. See test 3, Table 14.
24.8	135	112.9	22.6	35.0	Average during evaporation test. See test 1, Table 14.
25.1	133	114.2	19.3	32.6	Average during evaporation test. See test 2, Table 14.

Note.—During the time the first five observations were made the injection valve was not changed, the five observations being made within a space of about two minutes.

Tables VI, VII and VIII give data which may be used for comparing the amount of cooling water required with the two types of condensers shown in Figs. 1 and 3.

It will be noted that in Table VI the amount of injection water used was varied, though the amount of vacuum in the first five readings remained practically the same. In the last two observations, however, with reduced injection the vacuum decreased, the temperature difference remaining at 15 deg. In other words, we may be assured that with this condition the minimum possible temperature difference was obtained.

The observations shown in Table VII give temperature differences ranging from 16 down to 7.5, with greatly decreasing vacuum. Here, also, the equilibrium point was obtained, the average temperature difference being something like 12. Condenser Type V is exactly like condenser III, Fig. 3.

The first five observations of Table VIII were obtained in an attempt to ascertain the lowest possible injection water requirement for condenser A, which is of the counter-current type. It will be noted that the

average temperature difference for these five observations was a little less than 15.

With the minimum temperature difference of 7.5 for condenser Type V the weight of cooling water for a vacuum of 26 in. and the injection temperature of 80 deg. would be 27.07 lb. With a temperature difference of 14, the weight of cooling water for the same standard conditions would be 23.24 lb. In other words, the counter-current condenser would seem to be capable of operating with some 17 per cent less cooling water than is required for condenser Type V.

The last three horizontal lines of Table VIII give the averages obtained during evaporator tests using condenser Type I. It will be noted that the weight of cooling water per pound of vapor varies from 19.9 to 35.0 lb. with the same vacuum, the difference being doubtless due to carelessness in handling the injection valve.

Table IX gives condenser data obtained by Professor Kerr while making various evaporator and vacuum pan tests. This table gives data of considerable interest, though it is not very definite as regards a comparison of counter-current and parallel-current condensers.

TABLE IX

1	2	3	4	5	6	7	8	9	10	11	12	13	
Service	No. of Test	Vapor Condensed per Minute, Lbs.	Type of Condenser	Diam. Condenser, Inches	Vacuum	Temp. due to Vacuum	Temp. Leg Pipe	Temp. Difference	Temp. Injection	Injection per Lb. Vapor, Lbs.	Injection per Lb. Vapor, Corrected, 26" and 80°	Vapor Velocity (Gross) in Condenser, F. P. S.	Remarks
Quad........	1	534	Counter current..........	78	24.8	135.0	112.9	22.6	80.4	31.94	45.58	37.3	
Quad........	2	588	Counter current..........	78	25.1	133	114.2	19.3	80.4	30.67	40.93	43.1	
Quad........	3	610	Counter current..........	78	24.8	135	130.3	5.2	81.0	20.7	26.26	42.5	
Quad........	4	410	Parallel current (Spec.)....	36	24.1	140.5	114.5	26.0	81.0	31.00	55.34	118.5	
Quad........	5	452	Parallel current (Spec.)....	36	23.5	144.0	115.4	28.6	80.4	29.7	64.0	118.2	
Quad........	6	327	Parallel current (Spec.)....	36	25.4	130.5	112.3	18.2	80.0	32.1	39.25	......	
Quad........	7	185	Counter current (central)..	......	26.9	118.0	116.3	17.0	66.2	20.62	17.7	......	
Quad........	8	292	Counter current (central)..	......	26.2	124.0	111.2	13.8	66.2	23.0	33.66	......	
Quad........	9	173	Counter current (central)..	......	26.0	125.5	122.1	3.4	66.6	18.46	25.1	......	
Quad........	10	230	Counter current..........	60	26.3	122.5	114.5	7.9	92.8	47.28	28.22	36.7	
Double......	15	182	Counter current..........	48	22.06	152.4	146.6	5.8	64.6	12.33	26.67	22 .0	
Double......	16	180	Parallel current..........	......	24.77	135.6	118.0	17.6	72.4	22.66	38.38	......	
Vacuum pans.	1	217	Parallel current..........	54	24.06	140.4	109.4	31	81.0	36.75	74.77	27.9	Straight strike.
Vacuum pans.	2	153	Parallel current..........	54	25.0	133.8	104.6	29.2	81.0	44.31	66.4	23.7	Mixed strike.
Vacuum pans.	3	69	Parallel current..........	54	25.8	127.2	94.7	32.5	81.0	76.84	83.52	12.9	Crystallizer strike.
Vacuum pans.	5	112	Parallel current..........	......	25.58	129.9	119.1	10.8	86.5	31.57	30.66	......	
Vacuum pans.	......	245	Counter current (central)..	......	23.6	143.3	125.5	17.8	70.0	18.5	38.66	......	
Vacuum pans.	......	265	Counter current (central)..	......	22.92	147.3	124.3	23.0	70.0	19.0	47.83	......	

The actual injection per pound of vapor is given in column 11. These values, however, were obtained with varying vacuums and varying temperatures of injection water, for which reason they are not directly comparable. For this reason the weight of injection water per pound of vapor has been corrected to a standard vacuum of 26 in. and an injection temperature of 80 deg. These corrected values are given in column 12.

The values in column 13—namely, vapor velocities in condenser—are based on the assumption that a condenser is a cylinder without trays, and equal to the cubic feet of vapors per second divided by the cross-sectional area of the condenser shell. The results, though, are somewhat erratic, and this is quite natural in view of the careless operation of many of them.

A general inspection of column 12, however, shows considerable advantage for the counter-current type of condenser. The average of ten tests made on the counter-current condenser shows 33.06 lb. of injection per pound of vapor condensed. An average of eight tests made on parallel-current condenser shows 56.3 lb. of injection per pound of vapor condensed. Condensers Type I and Type V were in the same factory and observations were made throughout several weeks in order to get a comparison of the actual weight of the cooling water required per pound of vapor in the regular operation of the factory. The average temperature difference for condenser Type I was 16.5 deg. and for condenser Type V 25.5 deg. With standard conditions—that is, with 26-in. vacuum and 80-deg. injection water—these temperature differences would correspond to 35.8 lb. of injection per pound of vapor in the case of condenser I and 52.3 lb. for condenser V; in other words, condenser V required 43 per cent more injection water than condenser I. This shows a greater difference than was shown in the observation referred to above.

Anaconda Notes.—From the June issue of *The Anode*, the safety bulletin published by the Anaconda Copper Mining Co., we note that No. 1 section of the concentrator, which was recently remodeled to provide for the installation of the oil flotation process, is successfully treating ore at the rate of 2000 tons per day and is making a tailing that assays well within the limits expected. No. 2 section is now being changed to provide for the use of the same process and rapid progress is being made with the work. It is expected that the entire task of tearing out the old machinery and constructing the new 2000-ton section, ready for operation, will be accomplished by August. All four furnaces in the East Reverberatory Building are now operating on pulverized coal. Three of them are 143 ft. in length and the fourth, which was the first furnace to be equipped for coal dust firing, is 124 ft. long. These four are running nicely and are smelting a greater amount of material than the eight grate-fired furnaces formerly did. All furnaces in the West Building are now being rebuilt and will be ready for operation when the No. 2 Roaster Plant is completed. In the Coal Pulverizer Plant the Pulverizer Building is now completed and work is progressing on the installation of the balance of the crushing, storage and drying equipment.

The Morse Bros. Machinery and Supply Company, of Denver, Col., has purchased the entire power plant recently erected at Wilkenburg, Ariz. This plant was built to furnish power for the Octave Mining Company, fourteen miles distant, the power being generated at the railroad and transmitted to the mine. The plant consisted of 200 and 550-kw. Westinghouse alternators driven by Corliss engines. The steam plant consists of B. and W. Boilers, fired with oil. The transmission line was operated at 22,000 volts and is fourteen miles long. All of this material will be dismantled and sold, or removed to Denver. The smaller unit was in use three weeks and the larger one was never used.

The Electric Furnace for Reheating, Heat Treating and Annealing*

BY T. F. BAILY

More than a quarter of a century ago the first commercial electric furnace was put into operation for the melting of steel. This furnace, of less than 100 kw. capacity, showed on its preliminary operation a current consumption of 7000 kw.-hr. per ton of metal melted. Had this furnace been operated in America at the then commonly prevailing rate for electricity, at, say, 10 cents per kilowatt-hour, there would have been little hope that such a process requiring a heating medium of such great cost would ever become commercial. In the twenty-five years that have passed since this early and crude development of electric melting and refining furnaces, there have been put into service more than 100 of these furnaces, ranging in commercial capacity from 1 to 20 tons, and in electrical capacity from 100 to 3000 kw. Central stations that twenty-five years ago considered 10 cents per kilowatt-hour a low rate are now, with modern equipments of power generation, furnishing electric furnaces with current for less than ¾ cent. Electric furnace loads running into thousands of kilowatts, where now there are but hundreds, operating continuously and with power factors closely approaching unity, will undoubtedly cause central stations advantageously located to look with favor upon rates of ½ cent a kilowatt for such loads. As the dominating factor in electric furnace operation costs must always be the cost per kilowatt-hour, the gradual reduction in the cost of electric current will greatly add to the growth of electric furnace loads for re-heating, heat-treating and annealing.

Early Methods of Re-Heating by Electricity

One of the earliest attempts at electric heating was by direct resistance, wherein the materials to be heated were clamped between two massive terminals of an electric circuit, or, as in the water pail forge for small material, where one end of the bar was connected to a suitable terminal while the free end of the bar was plunged into a bath of water and other suitable liquid conducting material which was in turn connected to the other terminal of the electric circuit.

Both of these methods have two distinct disadvantages which prevented them ever becoming commercially feasible. The first and most serious is the matter of obtaining a suitable contact between the material to be heated and the electric terminal. The other inherent disadvantage is that at the point where the electric connection is made that part of the material to be heated must of necessity be of a different temperature than the rest of the bar.

From an operating standpoint, this method of heating is very inconvenient, as electrical connection must be made for each piece to be heated, and on account of the enormous current involved these contacts must be carefully made or there will be serious burning of the metal at this point, which would not only destroy the electrical terminal itself, but also burn the bar.

In any event, this method of heating could not be adapted to any but material of uniform cross-section, and in all probability there would be a much higher temperature in the interior of the bar than on the surface, due to the peculiar heating effect of an electric current flowing in a conductor.

*A paper presented before the Engineers' Society of Western Pennsylvania. In connection with this paper former papers by Mr. Baily may be compared in our Vol. 9, page 262 (May, 1911), and Vol. 10, page 291 (May, 1912), where illustrations of this furnace type may be found. An illustrated description of a Baily annealing furnace for brass and German silverware was given in our Vol. 12, page 483 (July, 1914).—Editor.

Re-Heating Furnaces with Granular Resistors

The type of furnace that seems best adapted for re-heating operations is the resistance type, in which the material to be heated is entirely separate from, and independent of, the resistance elements in which the heat is generated by the electric current. This arrangement makes for the maximum simplicity and convenience in operation. A general description of this type of furnace is as follows:

Through the side walls of a furnace shell made of suitable refractories are inserted two carbon or graphite electrodes. The inner ends of these electrodes extend into a trough of highly refractory material. This trough is filled with the resistance material itself, usually some form of broken carbon, and makes contact at each end with the electrodes. The outside ends of the electrodes are connected by means of suitable copper terminals and cables to the regulating transformer and switch, by means of which the voltage impressed across the furnace is regulated, the voltage thrown on the furnace having a definite relation to the current flow and heat input. The material to be heated is placed conveniently adjacent, at the side or above or underneath the resistance material and its containers, as the case may be.

In some heating operations the actual cost of heating per ton is less with electric furnaces than with combustion furnaces, while in some heat-treating and annealing operations the precision with which the operations are carried on must be the justification for the higher cost of heating in the electric furnace. In a general way it may be stated that the higher the temperature at which the heating operation is conducted the higher the relative economy in the use of electric furnaces. At the lower temperature there is less difference in the thermal efficiency of electric and combustion furnaces, but here the electric furnace shows great superiority in the way of temperature control.

The principal advantages of electric furnaces over combustion furnaces for re-heating are more accurate temperature control, non-oxidizing atmosphere, saving in space, elimination of blast or stack, evenness of temperature throughout the heating space, simplicity of control, small amount of heat lost to the surrounding atmosphere, and cleanliness of surroundings.

Electric furnaces of the character described may be controlled with great precision, for the reason that a given input of electric current liberates a given quantity of heat units within the furnace, the transfer of electric current to heat being at 100 per cent efficiency. The walls and doors of the furnaces are the only means for the escape of heat from the furnace in other than useful work, and this loss remains constant for any given temperature and operating conditions. For a given tonnage of metal to be heated to a certain temperature in a given time, it is only necessary to know the heat absorbed by the metal in coming to the temperature and the heat lost by conduction and radiation from the furnace. The voltage across the furnace terminals is then adjusted so that the kilowatts per hour required to deliver the necessary heat are just sufficient to deliver this heat.

In contrast with this simple method of delivering heat into the furnace, the combustion furnace requires that a given quantity of air be mixed with the fuel, and this process of converting chemical energy into heat is not usually conducted at an efficiency closely approaching 100 per cent, as in the conversion of electricity into heat. Besides this, the stack or discharge flues to the combustion furnace are an ever present means of carrying out what should have been useful heat under ideal operating conditions. Any variation in the supply of air or the supply of fuel in a combustion furnace quickly

affects the temperature, and both of these do continually vary, both in volume and pressure.

In order to obtain good commercial efficiency in a combustion furnace, an excess of air over the theoretical amount is required. This excess of air creates an oxidizing atmosphere in the furnace chamber which results in scaling the metal under treatment, resulting in a loss of from 1 to 5 per cent, depending upon the type of combustion furnace, the temperature, and the man operating the furnace. The smaller of these figures applies to annealing furnaces of large capacity, while the larger figure is not uncommon in oil or gas-fired heating furnaces for forging stock running at high temperatures. One of the factors contributing to the reliability of electric furnace operation is that electric current supply, whether from central station or from isolated plants, is much more dependable than either oil or gas, and under more ready control than even direct firing.

The space required for electric furnaces is considerably smaller than that required by combustion furnaces, due to the fact that no stack nor combustion chamber is required, and the electric cables carrying current to the furnace require much less space and are far safer than gas or oil lines, and much more readily located.

As the heat from the resistance units is thrown on the hearth almost entirely by radiation, the temperature of the furnace is more readily kept uniform over the entire area than in combustion furnaces where the heat is delivered to the hearth by the impinging heated gases or products of combustion. Another feature leading to evenness of temperature throughout the electric furnace is that the resistors of the electric furnace may be run at only a comparatively small temperature above that of the hearth of the furnace, while the combustion furnace, for instance in an annealing operation, requires that the incoming gases from the combustion chamber must of necessity be several hundred degrees higher than the desired ruling temperature of the furnace.

Mention has already been made of the precision with which electric current may be supplied to the furnace. It should be noted further, however, that the instruments for indicating and recording electricity are far more accurate than those available for indicating and recording the flow of fuels to combustion furnaces. Thus the heating costs of electric furnaces may be very readily obtained on any particular class of work, as the kilowatt-hours registered over a given run are readily ascertained.

In the summer months the heat given off by combustion furnaces, either by radiation through the walls of the furnace itself or from the waste products of combustion, if small furnaces are used, produces such extreme room temperature around the furnaces as to seriously affect the operator and markedly reduce the output of the furnaces. In contrast with this the loss of heat through the walls of an electric furnace is so small as to be almost negligible.

The actual theoretical heat required expressed in kilowatt-hours per ton of metal is given in Table I for heating to the temperature given.

The thermal efficiencies of electric furnaces vary greatly with the size and capacity in tons per hour. The wall loss on a forging furnace of 60-kw. capacity heating 250 lb. of steel per hour to 2200 deg. Fahr., will be approximately 30 kw., showing a thermal efficiency of 50 per cent. A furnace of 1 ton per hour capacity for 2200 deg. will show an efficiency of 75 per cent.

In annealing work a furnace of 100-kw. per hour capacity will heat 600 lb. of metal to 1650 deg. with an efficiency of 50 per cent, while a furnace of 600-kw. capacity heating 3 tons of steel per hour will show an efficiency as high as 90 per cent. All the above figures are typical for the usual classes of work handled in the capacity named.

First Commercial Furnace for Re-Heating

The first type of these granular resistor furnaces for re-heating was designed for heating small bars and billets such as are used for small forgings, and for temperatures up to 2300 deg. The general construction of these furnaces was as follows: The furnace proper was constructed of firebrick much after the method of prevailing oil-fired furnaces. Through the sides of the furnace were inserted large electrodes, the inner ends protruding into the furnace chamber. Foundry coke crushed to pea size was placed in the space between the electrodes and formed the resistor of the furnace. The opening to the furnace was in front, and the bars of metal to be heated were placed directly over the resistance body but not in contact with it. The necessary variable voltage supply to this furnace was regulated by the field rheostat of a small single-phase alternator. This furnace was run commercially for several weeks in place of the oil-fired furnace usually used for the hammer and on various sizes of material, as shown by the data given in Tables 2 to 5.

TABLE I

Material	Deg. Fahr.	Kw.-Hr. per Ton
Iron	2200	230
Iron	2000	215
Iron	1800	200
Iron	1650	170
Iron	1500	150
Iron	1250	115
Iron	900	75
Copper	1400	90
Brass	1300	85
Aluminum	950	140
Aluminum	750	110
Silver	1300	50
German silver	1300	75

TABLE II

Time of Charging	Volts	Amperes	Number Pieces	Size Stock in Inches	First Cut	Second Cut	All Out
9.50	150	270	6	1¼x132	10.15	10.25	10.45
10.55	100	260	3	1¼x 66	11.11	11.15	11.28
12.23	150	270	8	1¼x180	12.38	12.44	12.55
1.00	153	260	8	1¼x180	1.12	1.20	1.37

TABLE III

Time of Charging	Volts	Amperes	Number Pieces	Size Stock in Inches	First Cut	Second Cut	All Out
9.25	127	340	8	1½x¾x5 ft. 10	9.33	9.38	10.42
10.51	122	350	8	1½x¾x5 ft. 10	10.58	11.01	11.19
12.32	128	330	Metal un	forged at noon	12.38	12.41	1.25
1.27	132	330	8	1½x¾x5 ft. 10	1.35	1.38	2.44

TABLE IV

Time of Charging	Volts	Amperes	Number Pieces	Size Stock in Inches	First Cut	Second Cut	All Out
1.20	230	180	5	1¼x24	1.40	1.51	2.07
2.08	230	180	7	1¼x24	2.30	2.34	3.08
3.17	208	200	7	1¼x24	3.30	3.36	3.52
3.55	204	200	7	1½x24	4.01	4.07	4.29

TABLE V

Time of Charging	Volts	Amperes	Number Pieces	Size Stock in Inches	First Cut	Second Cut	All Out
3.55	240	140	8	¾x27	4.00	4.02	4.25
4.26	172	150	8	¾x 9	4.30	4.33	4.36
4.37	252	120	9	¾x22	4.40	4.44	4.55
4.57	280	120	8	¾x 9	5.01	5.04	5.07

Some of the difficulties encountered in this furnace besides its rather low thermal efficiency were burning off of the electrodes at the point where they emerged from the furnace; the burning out of the refractory materials supporting the resistance material itself; trouble with electrical connections between furnace cables and electrodes, and great variation in the electrical resistance of the resistance material itself.

The Electric Furnace for Re-Heating

In the six years that have elapsed since the construction of this early furnace, these difficulties have been well overcome. By the use of a steel shell for the outside wall of the furnace instead of brick, and with this space filled with suitable insulating material, the thermal efficiency of the small furnaces has been very materially increased, as is shown by the accompanying test sheet on a 30-kw. furnace. The burning off of the electrodes at the place where they leave the furnace walls has been entirely eliminated, one set of electrodes lasting for months at a time in continuous service.

TABLE VI—TEST OF A 30-K.W. ELECTRIC FURNACE

Time of Charge	Wattmeter, Kw.-Hr.	Voltage	Temperature of Stock	Number Pieces 1¼"x¾" x16"	Remarks
Start 5.15 p.m. 5.30	10,971 10,981	25	2200	15	Estimated initial temperature of furnace, 2400 deg. Fahr.
Start 5.40 5.55	10,981 10,990	25	2200	15	Voltage changed to 30 at 5.45. Voltage changed to 25 at 5.50.
Start 5.55 6.13	10,990 10,999		2200	15	
Start 6.13 6.30	10,999 11,009	25	2200	15	Voltage changed to 30 at 6.28.
Start 6.30 *6.50	11,009 11,019	30	2200	15	Voltage changed to 25 at 6.40. Voltage changed to 30 at 7.20.
Start 7.28 7.49	11,033 11,052	30	2200	15	Voltage changed to 25 at 7.41.
Start 7.54 8.12	11,055 11,068	25	2200	15	Voltage changed to 30 at 7.54. Voltage changed to 25 at 8.05.
Start 8.18 8.33	11,072 11,080	25	2200	15	Voltage not changed.
Start 8.38 8.56	11,082 11,093	25	2200	15	Voltage changed to 30 at 8.48.
Start 9.01 9.20	11,098 11,110	30	2200	15	Voltage changed to 25 at 9.03.
Start 9.27 9.43	11,112 11,120	25	2200	15	Voltage not changed.
Start 9.49 10.20	11,122 11,138	25	2200	15	Voltage changed to 30 at 10.00. Voltage changed to 25 at 10.11.

Duration of test, 5 hrs., 5 min.
No resistance material used. Current left on at 20 volts.
$11{,}138-10{,}971=167$ kw.-hr. power used.
$1\frac{1}{4}\times\frac{3}{4}\times16\times0.2834=4.25$ lb. weight per bar of steel.
$15\times12=180$, total number of bars heated to 2200 deg. Fahr.
$4.25\times180=765$, total number of lb. of steel heated to 2200 deg. Fahr.

$$167\div\frac{765}{100}=21.83 \text{ kw.-hr. per 100 lb. of metal heated.}$$

$20\times21.83=436.6$ kw.-hr. per ton of metal heated.
Temperature difference, 2150 deg.
Specific heat of steel, 0.199 approx.
$2150\times0.199\times765=327.305$ B.t.u. required to heat metal.
$167\times3412=569.804$ B.t.u. used in furnace.

$$\frac{327.305}{569.804}=0.575 \text{ efficiency.}$$

*One piece removed that had obtained required temperature.

The troubles encountered in connecting the electric cables to the electrodes have been eliminated, so that no trouble is experienced now from this source. For furnace temperatures not exceeding 2500 deg. Fahr. this type of furnace will answer every reasonable requirement, and in operating cost will compare very favorably with oil furnaces, figuring electrical energy at 1 cent per kilowatt-hour and oil at 4 cents per gallon, so far as actual fuel cost alone is concerned, while there is an additional saving due to the non-oxidizing of the metal amounting to a saving of from 2 to 5 per cent of the metal heated. This type of furnace is suitable for tonnages up to 1 ton per hour capacity, and billets not exceeding 4 ft. in length.

Continuous Furnaces

For furnaces in capacities of 1 ton per hour and above, the continuous type of billet heating furnace offers some advantage in economy as well as in mechanical operation, as in the continuous type only the discharge end of the furnace reaches the full ruling temperature, the lower temperature of the feeding end reducing wall loss of the furnace very materially. The following calculation of a heat balance sheet may be taken as typical for this type of continuous billet heating furnace heating material to 2000 deg.:

Capacity, 10 tons per hour; temperature, 2000 deg.; wall loss in kilowatt-hour, 250; theoretical heat required per hour by metal in kilowatt, 2150; kilowatt-hours per ton of metal heated, 240; cost of heating per ton with current at ½ cent per kilowatt, $1.20.

This figure of cost per ton of metal heated becomes prohibitive unless account is taken of the metal loss due to the oxidizing influence of the flame in gas-fired billet heating furnaces. Even making allowances of 2 per cent on $20 steel, this type of furnace seems to have no prospect of competition for large tonnages unless the cost of electric current is under the rate named in the above tabulation. In heating higher grades of steel, especially steel of crucible quality, the saving in scale over any combustion furnace practice will far outweigh the higher cost of heating by the electric furnace.

Combination Gas and Electric Furnaces

In large tonnages of heavy billets a combustion furnace using producer gas firing to, say, 1500 deg. Fahr., or above, and heating from this temperature to the desired rolling temperature by electricity, offers advantages of low fuel cost per ton of metal heated, at the same time a minimum amount of oxidation of the metal, as the low ruling temperature of the gas end will permit a high thermal efficiency even with a non-oxidizing flame, while the final heating is done in the electric end of the unit which is readily maintained under a reducing atmosphere.

Such a furnace as this can be expected to show a thermal efficiency in the gas end of 50 per cent and in the electric end 75 per cent. With coal at $2 per ton and electricity at ½ cent per kilowatt, the total cost of heating should not exceed for coal alone 10 cents and electricity 32½ cents, making a total cost of 42½ cents per ton.

This cost compared with a direct-fired heating furnace having a coal consumption of 200 lb. per ton of metal heated, would show an excess cost for the combination gas and electric furnace of 22½ cents per ton. But with a saving of 2 per cent in metal worth $20 per ton, the combination gas and electric furnace would show an actual saving of 17½ cents per ton of metal heated, besides giving to the metal all the advantages of the precision in uniform temperature throughout the billets, as well as a uniform rolling temperature.

Soaking Pits

The type of electric furnace which seems, however, to be destined to have the largest commercial application in rolling mill operations is the soaking pit, and it is doubtful whether any gas-fired pits of large size can compete in cost of operation with electric pits where

current is supplied at the usual rates of electric current available for this service, provided the ingots are charged hot into the furnace. A heat balance sheet for an hour-hole soaking pit holding sixteen 3½-ton ingots and having passed through it 648 tons per twenty-four hours would be as follows, assuming a wall loss of 500 kw. per hour:

With ingots stripped hot, interiors molten, no heat required for the metal itself, the current consumption would then be 500 kw.-hr. per 27 tons of ingots, or less than 20 kw.-hr. per ton of ingots soaked. With ingots averaging 1650 deg., the current consumption for 27 tons per hour would amount to 1620 kw. per hour, or a current consumption of 60 kw.-hr. per ton absorbed by the metal. To this should be added 40 kw.-hr. per ton as wall loss. This higher figure for wall loss per ton of metal heated being due to the reduced capacity of the pit in tons per hour when handling the cold ingots on account of the longer time required for heating and soaking. Thus the current consumption for ingots charged at 1650 deg. would be 100 kw.-hr. per ton.

With cold ingots the heat absorbed by the metal will be 230 kw.-hr. per ton, and with a wall loss under this condition of 185 kw.-hr. per ton 315 kw.-hr. per ton would be the current required for cold ingots. But as cold ingots are a rather small percentage of the total ingots handled in a modern steel mill, these high figures are of no serious consequence in considering electric furnaces for soaking pit operations.

It is apparent from these calculations that electric soaking pits can compete with gas-fired pits, even where moderately hot stripping and charging is practised. Besides this, the electric pit, as in the heating furnaces mentioned before, has the advantage of a non-oxidizing atmosphere, which will mean a saving of from 1 to 2 per cent of the weight of ingots put through the pit. Another advantage worthy of note is that an electric pit will take only one-third the space of a gas-fired pit of the same capacity. A feature of even greater importance than almost any other is the elimination of surface defects in the ingots, due to scale or oxidation, a matter now receiving considerable attention by steel makers.

Electric Furnaces for Heat Treating and Annealing

The rapid growth of the practice of heat-treating and a realization of the precision with which this treatment must be carried on in order to secure uniform results, has opened a particularly desirable field for the electric furnace, especially as the electric furnace can be more accurately controlled and a greater uniformity of heat throughout the furnace maintained in commercial operation than with combustion furnaces. A comparatively slight variation in either blast pressure or fuel supply in a combustion furnace very quickly affects the ruling temperature, while in the electric furnace, owing to the comparatively great mass of heated refractory material of walls and roof acting as a heat storage or accumulator, the variation in temperature is reduced to a minimum. In practice the current may be off for periods of an hour at a time without affecting the temperature more than a few degrees.

This type of furnace may be described as follows: In the usual steel sheet is constructed an arched roof of firebrick, so arranged as to reflect the heat radiated from the resistor troughs onto the hearth located between the two resistor units running lengthwise of the furnace. The material to be heated is handled through the doors of the furnace located in the end walls. The hearth, if not subject to mechanical abrasion, is made of suitable firebrick. Where the abrasion is likely to be severe, cast-iron plates replace the firebrick.

A heat balance sheet of a furnace of this type of 100-kw. capacity and the hearth area 5 by 6 ft. and heating 600 lb. per hour to 1650 deg. Fahr., will show the following efficiencies:

Heat absorbed by the metal, 50 kw.
Heat lost through the walls, 35 kw.
Heat lost through the doors and door openings, due to the frequent charging and withdrawing, 15 kw.

Continuous Furnaces

For furnaces of more than ½ ton per hour capacity, and for higher thermal efficiencies, the continuous type of furnace is desirable. The material, if of uniform section, is pushed through the furnace by direct application of the pusher to the material to be heated. If the parts are small or liable to buckle if direct pressure is exerted on them, they are placed in pans or steel boxes, these containers being pushed through one at a time. If the material is in the form of rods that may be handled through the furnace lengthwise, as, for instance, copper and brass rods or tubes, this material may be placed on steel pans and drawn through the furnace by means of hook and chain, as is common in brass mill practice.

A typical furnace of the continuous type for annealing German silver or brass stampings in steel pans has a hearth 15 ft. long by 2 ft. wide, and a rated electrical capacity of 200 kw. A mechanical charger operated by a motor-driven winch with hand-operated clutch pushes the pans in through the charging door one after another, seven pans being in the furnace at one time. The pans passing through the furnace are supported by a hearth made of cast-iron grids each 2 ft. square. The pan when discharged is dumped automatically into a water-sealed discharge hood. The metal under treatment falls into a tank of either clear water or pickling solution, depending upon the cleanliness of the material before it is charged. The pan is caught by two rails and held suspended above the trough. It may be taken out from under the water-sealed hood through the counterbalanced swing door.

In operating the furnace, a pan filled with material to be treated is placed on the runway in front of the pusher. The small hand lever near the top of the furnace frame operates the clutch on the motor-driven winch on top of the furnace. The first movement of the cylinder raises both doors enough to admit the pans, which are 3 in. high; a stop on the cable holds the doors at this height while the pan of fresh material is pushed into the furnace. As the fresh pan enters, the pan at the discharge end is pushed onto a dumping carriage, its own weight automatically tips the pan dumping the contents into a hopper, the lower end of which is submerged in the quenching tank; the annealed material falls into a perforated copper basket, which at intervals is lifted out of the quenching tank. As the pan starts to tilt, the pusher carriage is pulled out of the charging end and the doors are dropped. Thus in this furnace the material is not exposed to the atmosphere at any time after entering until taken cold from the quenching tank. This entirely eliminates the possibility of oxidation as the furnace itself has a reducing atmosphere. A heat balance sheet of this furnace annealing German silver at 1400 deg. Fahr. shows the following:

Heat absorbed by 2000 lbs. of metal, 80 kw.
Heat absorbed by 400 lbs. of steel pans, 28 kw.
Heat lost through walls and doors, 24 kw.

A heat balance sheet of this furnace heating 1500 lb. of steel per hour to 1650 deg. will show the following:

Heat absorbed by 400 lbs. of pans, 34 kw.
Heat absorbed by 1500 lbs. of metal, 127½ kw.
Heat lost through walls and doors, 30 kw.

The advantage of this type of furnace over the non-continuous furnace is a lower labor cost and the fact

that the material when brought to the desired temperature may be more quickly removed, eliminating largely the danger of over-heating, and at the same time allowing the material under treatment to be brought to temperature more gradually.

Automatic Continuous Furnaces

The type of furnace best adapted to heat-treating which requires precision is the automatic continuous type, wherein the material under treatment, when brought to the predetermined temperature, is automatically discharged either into the air or into some quenching medium. This method of operation reduces the human element and the chance of error to a minimum. The only part of the operation dependent on the operator is the placing of the material to be heated on the charging platform. When the material at the discharge end of the furnace reaches the maximum temperature, a special pyrometer closes an electrical circuit, which in turn closes, through a suitable relay, the solenoid operated radial dial switch; the various electrical circuits in turn operate the doors, pusher and quenching apparatus.

A typical two-furnace equipment of this type having three operations, heating above the critical point, quenching and re-heating for drawing, consists of the following parts: Two furnaces, a quenching tank, a quenching machine, a control pulpit and two contact-making pyrometers. As all the motions of the equipment are controlled from one radial dial switch, the equipment, when once adjusted, is so interlocked that no material can get through the furnace unless it is first heated to the exact temperature (a maximum of 5 deg. Fahr. is allowed). Immediately upon reaching this temperature it is quenched and allowed to remain in the quenching bath a stipulated time; at the end of this time it is withdrawn from the bath and placed on the charging platform of the drawing furnace. When the material at the discharge end of the drawing furnace reaches the desired temperature, the pyrometer of this furnace sets in operation the operating mechanism, pushing into the furnace the material just brought out of the quenching bath and at the same time discharging the material that has come to temperature.

It is only by this automatic method that the highest class of work in heat-treating can be done, as the only part of the operation depending on the human factor is, as mentioned above, the placing of the material to be heated on the charging platform of the first furnace.

The greatest feature and one that cannot be emphasized too greatly is that when the material is delivered at the discharge end of the equipment it has received the treatment as per the setting of the control equipment, and nothing else. The greatest objection to heat-treatment as generally practiced to-day with combustion furnaces is due to the inability to obtain duplicate results. The automatic equipment just described eliminates the uncertainties of non-automatic equipments and enables heat-treating to be done with as great a precision as it is possible to measure. While with hand operation it is possible to obtain excellent results in actual practice at times, a considerable portion of the material treated will fall below the standard as determined by physical tests. The automatic equipment gives every piece exactly the same treatment.

Table VII

Carbon per cent	Treated or Untreated	Ultimate Strength	Elastic Limit	Elongation	Reduction in Area	Per Ton Cost of Electric Heat Treatment Current at ½c per Kw.-Hr.	Increase in Ultimate Strength	Increase in Elastic Limit	Increase in Cost for Heat Treating Steel Costing $30 per Ton
0.25	Untreated	73,000	29,000	24	50	......	..	...	......
0.25	Treated	112,000	70,000	10	50	$1.50	53%	140%	5%
0.45	Untreated	92,000	36,000	18	42	......	..	...	......
0.45	Treated	155,000	92,000	10	55	1.50	68%	153%	5%
0.65	Untreated	121,000	40,000	10	24	......	..	...	......
0.65	Treated	169,000	115,000	7	34	1.50	40%	188%	5%

Treatment consisting of heating to 850 deg. C., quenching in water, reheating to 550 deg. C.

Data taken from Harbord & Hall.

A tabulation of the results that may be obtained with costs of such a treatment as has just been described is given in Table 7:

It will thus be seen that for a comparatively small cost, steel of much better physical qualities is obtained.

Conclusion

In conclusion it may be stated that the small electric re-heating furnaces are commercially feasible from a fuel standpoint alone, where the current consumption per ton is 400 kw.-hr. and the rate is 1 cent per kilowatt-hour, compared with oil where the consumption per ton is 100 gal. at a cost of 4 cents per gallon, or natural gas where the consumption per ton is 12,000 cu. ft. at 33 cents per 1000 cu. ft. With an allowance made for the saving of metal due to absence of scaling in the electric furnace, the saving in heating cost per ton on the above will be that percentage of saving multiplied by the cost of steel per ton; as, for instance, 5 per cent saving on an automobile steel worth $50 per ton, or a net saving of $2.50 per ton of metal heated. On this basis of metal saving and with a consumption of 100 gal. of fuel oil per ton, in order to compete with electricity at 1 cent, oil would have to cost not to exceed 1½ cents per gallon, or with oil at 3 cents the fuel consumption would have to be under 50 gal. per ton.

Electric furnaces of the continuous type of 5 tons per hour capacity will show commercial economy over coal-fired furnaces of the same capacity which require 200 lb. of coal per ton of steel, with coal at $2 per ton, while the electric furnace requires an electric current consumption of 250 kw.-hr. per ton, current at ½ cent per kilowatt-hour, with a metal saving of 3 per cent over coal-firing, heating a steel worth $35 per ton.

The further advantage of electric furnaces will be, evenness in temperature throughout the billet, and uniformity of temperature one billet with another.

The combination gas and electric furnace will show commercial efficiency compared with producer-gas-fired furnaces using 200 lb. of $2 coal per ton, while the combination gas and electric furnace uses 100 lb. of coal per ton of metal for heating to 1400 deg. Fahr., and 100 kw.-hr. per ton in heating from 1400 deg. to 2000 deg., current at ½ cent per kilowatt-hour, coal at $2, and with a metal savings of 2 per cent on steel valued at $20 per ton.

In the case of soaking pits, the advantage in favor of electric pits is more marked in the way of commercial saving than any of the other electric heating furnaces mentioned, on account of the elimination of the usual metal loss by oxidation of 2 per cent which occurs in producer-gas-fired pits. With steel valued at $20 this item alone is 40 cents per ton. To this add a fuel cost of 5 cents per ton, making a total cost of 45 cents per ton of ingots soaked in producer-gas-fired pits. Electric soaking would cost only 10 cents per ton, current consumption being 20 kw.-hr. per ton of ingots, and the current at ½ cent per kilowatt-hour. This would mean a saving of 35 cents per ton over the prevailing method of operation, besides giving the additional advantage of saving in space, and ingots with surfaces as clean as when charged into the pit.

In heat-treating, the saving in operating cost of electric furnaces over combustion furnaces in most cases

must come in the elimination of oxidation, as, for instance, on high-grade steel, brass and non-ferrous metals, eliminating large expense in acid, and in labor for the pickling operation. In addition to this, the advantage which outweighs, perhaps, all others is the precision with which electric heat-treating may be done. It is obvious that it is useless to heat-treat a series of parts that may go to make up a steel structure, as a bridge, a line of rails, or a set of springs or axles of a locomotive, if the method of heat-treatment is such that dependence cannot be fully made on the gain in physical properties. The failure of a single member of the bridge or a single rail or a spring or axle is almost certain to cause a catastrophe, hence without absolute precision in temperature and method for producing that temperature in every piece alike vital parts of a structure or a machine must be figured on the basis of untreated parts, necessitating a greatly increased weight over that of a design relying on the greater strength of heat-treated parts.

The automatic electric furnaces described above give this precision, and when the material to be treated has come through the furnace it is certain that it has had the prescribed treatment, and nothing else.

The user of steel to-day is willing to pay the additional cost for the additional physical qualities to be obtained by proper heat-treatment, but he has never been willing and never will be willing to pay for the so-called heat-treatment that has in too many cases consisted of simply putting the material through a furnace. Physical qualities of the highest character have been obtained from time to time by treatment in combustion furnaces, but it is almost impossible to obtain duplicate results from day to day, owing to the many variables, including the greatest of all, the human element. The automatic electric furnace requires the minimum of attention in its regulation, and the human element is eliminated completely in the cycle of operation, excepting in placing the material on the charging platform of the furnace.

When the engineer realizes that for an additional cost of from \$2 to \$3 per ton he can with certainty get the full value of results possible with heat-treatment, the demand for heat-treated material will be a great many times larger than it is to-day.

Electric furnaces have come to stay, and while in the past a great deal of bad steel has been made in all classes of electric furnaces, it must be realized that the same sort of operators would probably have made a great deal worse steel in any other kind of furnace. The application of electric furnaces in melting and refining, and in heating and heat-treating, has only begun, and while the total current now used in this country in electric steel furnaces is only a few thousand kilowatts at this time, within the next ten years it should be several hundred thousand kilowatts. With the growth of electric furnace loads, with their high-load factor and power-factor, the cost of current per kilowatt-hour will be materially reduced, so that even electric smelting, when the high quality of pig iron thus produced is taken into consideration, may become, even in this district, commercially feasible for the better grades of iron to be used in the manufacture of high-grade steels, while electric furnaces for heat-treating, re-heating and the soaking of ingots will have come to hold the same relation and importance in industrial heating operations as the electric motor now holds in the field of industrial power.

* * *

In the extended discussion which followed Mr. Baily's paper, and which is given in full in the April issue of the *Proceedings* of the Engineers' Society of Western Pennsylvania, Dr. C. G. Schluederberg, Mr. Frank Thornton, Jr., Mr. T. D. Lynch, Mr. E. D. Leland and Mr. A. Stucki asked various questions.

Dr. J. W. Richards said for the sake of heat insulation that kieselguhr bricks should be used next the shell or casing, and the latter should be of a polished white metal, such as Monel metal.

Mr. William Hoopes said that "the Aluminum Company of America has lately installed one of the Baily furnaces, and it works. . . . This type of furnace is more flexible than any other type of furnace, i.e., the resistance type of furnace is capable of a more general application. It can be built in almost any size, and the resistance material is cheap and easily used."

With respect to the cost of electrical energy at ½ cent per kilowatt-hour, Mr. Baily said he thought that this "in large capacities includes all the charges, for instance, the investment charge as well as fuel. We have some furnaces now in operation that are operating under 2/3 cent per kilowatt-hour. This is from a central station, of course."

Prof. S. L. Goodale referred to a peculiar point which had come to his attention in heat-treatment experiments, from which it would seem to have been better to have an oxide scale formed than not. "I cannot say the effect is always found, but it certainly happens at times that when no oxide scale is formed the metal itself is decarbonized to a slight extent on the surface, resulting in a soft skin."

In reply to questions of Mr. Thomas S. Perkins on the cost of electrodes and maintenance cost, Mr. Baily said that "a typical furnace, 200 kw., has had two \$4 electrodes, and in the way of repairs to brickwork has had about twelve silica brick. It has run about 6000 hours. By a little carelessness the electrodes burned off owing to the resistor material over the electrodes becoming too thin.

"As to the adjustment of the control of the furnace, this will not need any changing for over a period of eight to ten hours or longer; the quantity of material going through the furnace is practically constant. If you have a lower capacity you have to reduce the flow of current into the furnace or the temperature of the furnace will, of course, increase. As to the voltage, take a forging furnace of 250 lb. per hour capacity, the voltage would be about 60 across the furnace. In a furnace of 600-kw. capacity, probably 18 ft. long, the voltage would be about 250. In some cases the two cores of the heat-treating furnace are run in parallel, thus doubling the voltage, cutting the amperage and cables in two by that method.

"The cost of the furnaces themselves will be roughly four or five times the cost of a combustion furnace of the same capacity. Take a typical forging furnace handling 250 lb. per hour would cost about \$1,200. A heat-treating furnace of 600-lb. capacity per hour would cost about \$2,500. A furnace of 2000-kw. capacity runs about \$25,000. These figures may be taken as typical for standard designs. . . .

"The control is obtained through special transformers called regulating transformers, controlling by special switches connected to the special taps of either the primary or secondary of the transformers. If we have to handle a primary voltage of 22,000 we control on the low-tension side. If we have a primary of only 440 volts we control on the high-tension side. All these furnaces are alternating-current furnaces. It is possible to use direct current, but in order to get voltage control a motor-generator set is required."

Single-phase furnaces are usually cheaper to build than two or three phase. A furnace of considerable size, say 1000 kw., would probably be built two-phase.

The voltage depends on the particular furnace, the highest used by Mr. Baily in an actual furnace is 400 volts. Above that there is danger of trouble with electric insulation.

Mr. Baily concluded his reply as follows: "The highest temperature we have ever operated furnaces at is 2700 deg. Fahr., and those furnaces run as long as three weeks without any repairs. At that time they required new linings, which cost about $4.00 and take half a day to renew, counting the time of cooling the furnace down.

"I think I have answered most of the questions that have been mentioned here. Some one has mentioned metal resistors. These seem to be quite feasible for temperatures up to 1500 deg. Fahr. About 2000 deg. they seem to go to pieces pretty rapidly, and are not really commercial at that temperature.

"The upkeep of the furnaces was asked for. We have recently put in operation some furnaces where the upkeep, renewals, etc., were guaranteed to be within 10 cents per ton of metal heated. That is a heat-treating operation. In small forging furnaces the cost will probably run as high as 50 cents a ton, using regular forging furnaces with ruling temperatures of the metal of 2300 deg. Fahr. in the small furnaces. The larger the furnace the less the cost per ton."

The Current Status of the Borax Industry

BY SAMUEL H. DOLBEAR.

The effect of political conditions in Europe has been felt less in the American borax industry than in almost any other branch of the chemical and mineral industry. Possibly this statement would be more clearly correct if it said that the net effect has been a normal production during the past year. On account of depressed business in the United States, local demand has, as a matter of fact, fallen off very considerably. On the other hand European refiners of borax and boracic acid, particularly those of Austria and Germany, have been badly crippled in their operations, and this has resulted in a large increase in American export trade. Canada, which has hitherto been supplied by England, has purchased large quantities from American refiners.

The world's commerce in boron compounds is practically controlled by Borax Consolidated, Limited, an English syndicate with headquarters at London. This company, in addition to its French and English refineries, also has refineries in Austria, and has supplied the German refiners with ore from its Chilean mines.

In Asia Minor the borax mines on the Sea of Marmosa normally produce about 14,000 tons per year. These mines are controlled by the British syndicate and have been for years an important source of ore for French and Austrian refiners. The mines at this point were worked many years before the development of the South American deposits. The participation of Turkey in the war has effectually shut off this source of supply.

In the United States, the mines of California are the only producers of borate ores. The largest production is from the deposits of the Pacific Coast Borax Company, which is now a subsidiary of Borax Consolidated. During the past year this company completed a narrow gage railroad connecting its Biddy McCarthy and Monte Blanco deposits with the Tonapah & Tidewater Railroad at Death Valley Junction. This work represents an expenditure of about $400,000 and opens up some of the best deposits in the Death Valley region. These deposits have hitherto been inaccessible on account of a long rough wagon haul. At Death Valley Junction this company has also built a large roasting plant in which the lower grade ores are calcined before shipment to the refineries.

The Sterling Borax Company, whose mines are located 6 miles from Lang, in Los Angeles County, ranks as second largest producer in California. During 1914 this company is reported to have mined about 15,000 tons of borate ore. This is divided into two grades, the first containing about 31 per cent anhydrous boracic acid; the second about 20 per cent. All of the ore is roasted at the mine before shipment, thereby eliminating impurities which consist of clay, pandermite and water. On roasting, the colemanite content disintegrates into a fine powder, while the pandermite and clay retain their original form. This makes it possible to separate the valuable portion very easily by screening. A branch railroad connects the mine with the Southern Pacific Railroad.

After a period of idleness lasting several years, the Russell Borax Mining Company is again working its mines in the Ventura fields, the control of the company having been acquired by the Stauffer Chemical Company of San Francisco. During the past year fifteen men were employed during the seven months' operating season and a production of 3800 tons was made. The ore mined was colemanite and averaged 37 to 38 per cent A. B. A.

The possibility of the development of an entirely new colemanite field is suggested by the discovery of this mineral in the Kramer section in San Bernadino County. While drilling for water on a ranch four miles from Rich Station on the Santa Fe Railroad, colemanite ore was encountered, the extent of which has been variously reported up to a thickness of forty feet. Little information is yet available regarding this occurrence, but the fact that the land has been purchased by the Pacific Coast Borax Company may be regarded as indicative, in a measure, of its importance.

The borate mines in Chili have been the principal source of this ore for many years, about 75 per cent of the world's supply being normally produced here. Ascotan, near Antofagasta, is the chief producing district. The Chilean mines, as well as those of Peru and Argentine Republic, are controlled by the British syndicate.

It is expected that Peru will become a producer shortly through an arrangement effected by Borax Consolidated with the Peruvian government. This agreement provides for the continuous operation of the mines situated near Arequipa, the construction of reduction furnaces capable of treating 40,000 metric tons annually, and the provision of either a railroad or other transportation facilities.

Although some borates are produced each year in Argentine Republic, none of the product is shipped, and only enough work is done to comply with the mining laws of that country. At Tres Morros the sun dried ore carries about 38 per cent A. B. A., and 1800 tons of such material was produced in 1913. The expense of production is high on account of the scarcity of fuel and distance from rail or water. It is not likely that borates from this country will be produced commercially until cheaper sources have been exhausted.

Borax prices are somewhat higher now than before the war. During the past year quotations for carload lots were at 4 to 4¼ cents per pound as compared to 3¾ to 4 cents in 1913.

Practically all of the borax and boracic acid consumed in the United States is refined in this country. Refineries are located at Bayonne, N. J.; Brooklyn, N. Y.; New Brighton, Pa.; Chicago, Ill., and San Francisco. The product of the San Francisco refineries is sold largely to Pacific Coast and Japanese consumers.

The Electric Furnace in the Foundry*

BY WILLIAM G. KRANZ.

The increased service demands on some of the products of the National Malleable Castings Company prompted it about eight years ago to investigate the electric furnace, both in America and in Europe. The process had already been sufficiently developed in Europe to lead us to believe that the electric furnace would most nearly meet our requirements.

After further investigation and consultation with the highest authorities on the subject, we decided upon the Heroult type as the simplest and most practicable.

In 1910, we built a furnace of this type, of 300 lb. capacity, for experimental purposes, and although it was crudely constructed the quality of the material we were able to make justified the installation of a 6-ton Heroult furnace in 1912.

This furnace has three electrodes, 17 in. in diameter, uses three-phase, 60-cycle current, and is equipped with Thury regulators, which give us good regulation and a uniform load on the line even when cold melting. The power factor of the furnace is 94 per cent.

Since July, 1912, the furnace has been in continuous operation, producing up to the present time over 20,000 tons of both carbon and alloy steels of varying analyses and of exceptional quality. Both cold and hot-metal charges have been used, with a power consumption of about 150 kw.-hr. per ton in the case of hot-metal charges and from 500 to 600 kw.-hr. per ton in the case of cold charges.

The electric energy consumed varies according to the final analysis of the steel and the amount of refining required. Too much cannot be said about the refining possibilities of the electric furnace, for no other method of steel manufacture can compete with the electric in this respect.

In proper operation lies the whole secret of success. That steel has been made electrically means nothing, for when the furnace is operated under oxidizing conditions the quality is no better than that of open-hearth material; but when properly made, electric steel is as good as that made in the crucible, and very much less expensive. The operation of the furnace is simple and the resultant composition is scientifically accurate. I might cite an example in this connection:

On a heat of steel treated under a slag of high-silica content some metallic aluminum was added in order to reduce the silicon from the slag in accordance with the following chemical equation: $3SiO_2 + 4Al = 3Si + 2Al_2O_3$. Analysis showed that the amount reduced was theoretically correct according to this equation.

The most important of the many advantages of electric steel castings over those made by the ordinary processes are briefly summarized below, and it should be kept in mind that these apply not only to carbon steels but to the alloy steels as well.

1. Absence of segregation, elimination of oxides, and absolute uniformity of composition regardless of atmospheric conditions which affect open-hearth furnaces.
2. Almost entire elimination of sulphur is possible (an important consideration in steel castings) and complete control of the other elements.
3. Great tenacity, giving ability to withstand much more abuse and fatigue without rupture.
4. High ratio of elastic limit to ultimate strength.
5. A more ready response to heat treatment and with much more uniform results.
6. Perfect control of pouring temperature, combined with ability to obtain very hot metal, so that light and intricate shapes are readily cast.

Let us take up the advantages of the more important of these qualities of electric steel, and investigate them more fully.

First.—Absence of segregation and oxides has been firmly established by a great many investigations in our chemical and microscopical laboratories. As a more practical proof of the elimination of oxides, we know that additions of any of the ferro-alloys to the bath will be found alloyed with the steel in their theoretical amounts. This is even the case with elements, such as aluminium and titanium, which are so susceptible to oxidation, proving conclusively in our minds that there could be no oxygen present in the steel. Leading authorities have agreed for some time that the electric steel furnace is the one means of preventing segregation.

W. R. Walker, in May, 1912, read a paper on "Electric Steel Rails" before the American Iron and Steel Institute, in which he stated that "Ingots of even eight tons had been produced electrically which were practically free from segregation."

Second.—We know of no authority who doubts the practical elimination of sulphur in electric-furnace operation. We have repeatedly reduced the sulphur to a trace in irons containing as high as 0.30 sulphur. The rapidity with which this reduction takes place depends somewhat upon the carbon content of the material, the sulphur reducing very much more rapidly in the higher carbon materials.

FIG. 1—TESTS WITH BASIC OPEN-HEARTH STEEL, ANNEALED, 213 CYCLES (UPPER PICTURE) AND ELECTRIC STEEL, ANNEALED, 345 CYCLES (LOWER PICTURE)

Third.—To illustrate the great tenacity of electric steel we submit (Fig. 1) exact reproductions (reduced) from two tests of two similarly treated specimens of steel, which are typical of a large number made on an Upton-Lewis toughness testing machine. One of these is electric and the other open-hearth, of almost identical analysis, as shown below. The marked superiority of the electric steel specimen, especially as to its tenacity, is shown in Table I.

Table I.—Comparative Properties of Electric Steel and Basic Open-Hearth Steel.

Electric Steel.

C, 0.24; Mn, 0.52; Si, 0.25; P, 0.010; S, 0.019.

Elastic limit	36,400 lb.
Ultimate strength	65,300 lb.
Elongation	36 per cent
Reduction	55 per cent
Toughness test (fatigue) to break	345 cycles

Basic Open-Hearth Steel.

C, 0.23; Mn, 0.53; Si, 0.24; P, 0.011; S, 0.038.

Elastic limit	34,800 lb.
Ultimate strength	63,000 lb.
Elongation	29½ per cent
Reduction	35 per cent
Toughness test (fatigue) to break	213 cycles

*A paper to be presented at the San Francisco meeting of the American Institute of Mining Engineers.

Fourth.—During the past year we have developed an electric steel having remarkable physical qualities after heat treatment. This was accomplished without resorting to any of the high-priced alloys. The steel, when subjected to shock or static pull, will stand from four to five times as much stress without distortion as the ordinary open-hearth product. This assertion is not based on a few tests, but on over 3000 made up to the present time.

We have made a great many similar tests of heat-treated open-hearth material, and have invariably found that in certain specimens the physical properties are impaired by the treatment rather than benefited. This is not, however, the case with the electric-furnace product. The old saying: "In order to make good bread you must start with good dough," we believe applies to the steel industry as well.

CONCLUSIONS

The greatest advantage of the electric-furnace process over all others is its uniformity of product. The open-hearth under certain conditions will, we know, produce steel of very good quality, but there are so many contingencies, such as atmospheric conditions, stack-draft, fuel and furnace variations, beyond the control of the operator, that absolutely uniform results are impossible.

Electric-furnace products are looked upon by some with skepticism, due to those who have adopted the process thinking it a panacea for all of their ills, and who have furnished the trade with products not worthy the name. The lack of knowledge and the inexperience of the operator should in no way condemn the process. The production of perfect castings does not entirely depend upon the quality of material of which they are made, but upon the foundry practice to a very great extent. Frequently excellent material is ruined by bad foundry practice. Nevertheless we feel that the electric furnace, with its perfect control of composition and temperature, fills a long-felt want in the industry.

National Malleable Castings Co.,
Sharon, Pa.

Synopsis of Recent Chemical and Metallurgical Literature

Crushing and Grinding

Hardinge Mill Data.—In a paper to be presented by Mr. A. F. Taggart at the San Francisco meeting of the A. I. M. E. in September, the author presents numerous data on Hardinge mill operation at different plants, and gives a summary, as follows:

	6 ft. by 16 in. Ball Mill	8 ft. by 22 in. Pebble Mill
Average maximum size of feed, mm....	44.5	9.7
Average size of feed, mm..............	9.0	1.26
Average maximum size of product, mm..	6.0	1.5
Average size of product, mm............	0.37	0.14
Average per cent of—200 mesh in product	28.9	37.0
Average per cent of—200 mesh in product, no slope	.....	44.3
Average per cent of—200 mesh in product, 0.5 to 4 in. slope....................	.....	31.6
Reduction ratio, range..................	7 to 67	6 to 15
Reduction ratio, average..................	39.6	8
Average size of product, no slope, mm...	.....	0.10
Average size of product, slope 0.5 to 4 in.	.....	0.17
Average tonnage	203	110
Average tonnage at no slope..............	.....	85
Average tonnage at 0.5 to 4 in. slope.....	.....	128
Average horsepower	35.06	35.6
Average charge, balls or pebbles, tons....	4	4.5
Average ball or pebble consumption, pounds per ton....................	0.51	1.94
Average relative mechanical efficiency...	53.2	20.5
Average percentage of water in feed.....	60	58.7
Average revolutions per minute.........	28	27.8

Gold

Gold Refining with an Electric Furnace.—At the Alaska-Treadwell cyanide plant an electric furnace has been substituted for a blast furnace for treating the by-products from the Tavener refining process. The by-products consist of slag, matte, flue-dust and refinery refuse. The operation is described by Mr. W. P. Lass in a paper to be read at the meeting of the A. I. M. E. in San Francisco next September.

A sectional view of the furnace is shown in Fig. 1. The body of the furnace was constructed from an old steel drum by cutting off the top and introducing a cable, made from strands of bare copper wire, through the bottom and spreading the strands out fan-shaped on the inside of the drum.

Powdered graphite, obtained by grinding up old crucibles, mixed with 10 per cent cement, was tamped wet into the bottom of the drum, around and completely covering the copper wires. The graphite was carried up to the bottom of the furnace, or lead-well, and acted as the lower electrode. The sides were built up of ordinary firebrick forming a melting chamber 14 in. in diameter by 20 in. high.

The upper electrodes, of graphite or carbon, are 3 in. in diameter and 40 in. long, arranged with joints en-

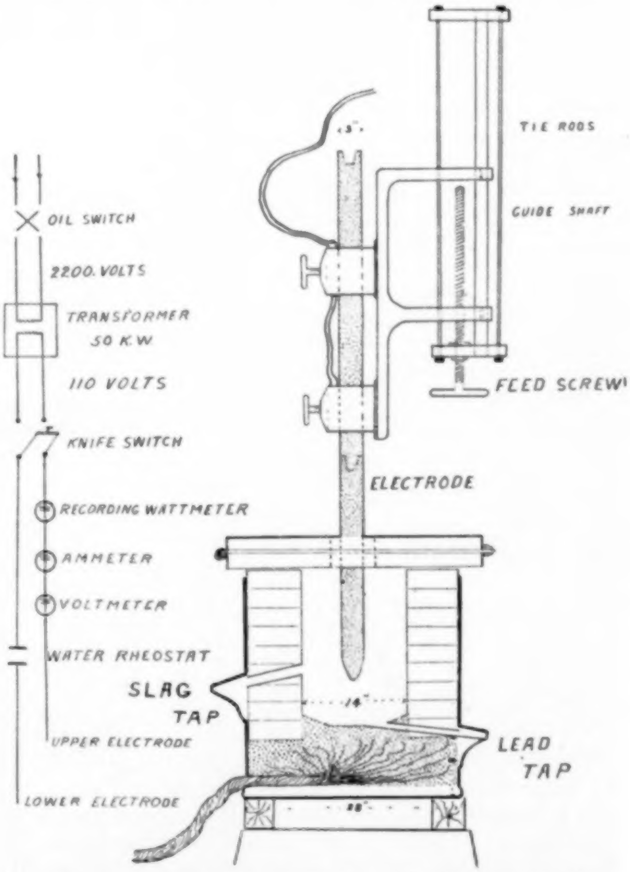


FIG. 1—SECTIONAL VIEW OF ELECTRIC FURNACE

abling new electrodes to be connected without shutting down or wasting stubs. A screw feed was arranged for raising and lowering the upper electrode.

The cover for the furnace had three openings, one for feeding the charge, one for the escape of gases, and one in the center for the introduction of the electrode. It was later found more practical to enlarge this center opening to 6 in. in diameter, to allow of a central feeding of the charge around the electrode.

A 4-in. pipe connected to a ventilating fan carries off the escaping gases.

The furnace is operated on the lighting circuit through a 50-kw. transformer, 60 cycles, 110 volts.

Later, a water rheostat, operated by raising and lowering one disk on another submerged in a barrel of water, was constructed to lower the voltage for use

when starting the furnace, or when there was a bath of metal in the bottom of the furnace that would otherwise allow too much current to pass and thereby cause short circuiting.

The material to be treated in the furnace is mixed in the following proportions: Refinery by-products, 100 lb.; old reverberatory hearths, containing 60 per cent CaO, 20 lb.; litharge, 20 lb.; coke, 2 lb.; scrap iron, 3 lb. About 160 lb. of the mixture is added for a charge. The total amount of material added during the melt is 8507 lb., of which 5870 lb. is by-product material (old slag, the residue from burning old mill launders, sweepings, etc.) of the following composition:

	Per Cent
SiO_2	40.1
Fe	16.0
CaO	16.1
Cu	5.9
Pb	3.0
Zn	5.7
Al_2O_3	2.0
S	3.6
Moisture	4.0
	96.4
Gold	$1,096.60 per ton

Coke is added to the charge as a reducing agent, only a quantity sufficient to throw down the lead being used.

The charge is introduced into the top of the furnace through the central opening around the electrode without removing the slab cover.

In starting, the furnace is operated as an arc furnace, until it has become thoroughly hot, when the charge, consisting of slag, brick dust, etc., is added, the electrodes being raised as the load in amperes increases, until the entire chamber is filled with the charge and the upper electrode extends into the melt almost a foot. As the charge continues to melt the electrode is moved down or up, keeping the amperage reading as nearly constant as possible. The raising or lowering of the upper electrode decreases or increases the power consumption and thereby affects the amount of heat generated.

At this stage the furnace is no longer operating as a simple arc furnace, but has automatically transformed itself into a resistance type of furnace, the semi-fluid or molten charge acting as the resistor, the current passing from one electrode through the center of the charge to the other.

After the charge is in quiet fusion, which takes on an average 2 hr. 10 min., the power is turned off and the charge allowed to settle for 15 min. before tapping the slag. This allows the lead to settle out, the furnace acting as a forehearth.

In operation, the molten lead and slag are tapped, as in the blast furnace. If the lead freezes it is melted by diverting current from the upper electrode and letting it pass through the lead, the tapping rod playing as an arc on the side of the furnace or into the lead tap.

The operators use colored or amber glasses to protect their eyes from the glare of the electric arc.

OPERATING DATA

Total running time	128 hr. 40 min.
Average weight of charge added	160.5
Average fusion time of charge	2 hr. 25 min.
Total number of charges	53
Graphite electrodes used	1 per 24 hr.
Total power for 128 hr. 40 min., kilowatt-hours	4,440
Power used per hour, kilowatts	34.50
Power used per pound of material fed, kilowatt-hours	0.52
Power used per ton of material fed, kilowatt-hours	1,044.0
Acheson graphite used per hour, feet	0.15
Material melted per hour, pounds	67.7
Material melted for 24-hr., pounds	1,625.0

The only item of cost for flux is the coke, 2 lb. per 100 lb. of by-product material or 118 lb. total being used, since the old reverberatory hearths furnish the lime; the cupels from bullion refining, the litharge, and mill scrap, the iron.

Both graphite and carbon electrodes are used, the former costing $2.95 each, and the latter $1.20. Power cost is less than 1c. per killowatt-hour.

The labor required for the operation of the furnace, including the work of charging and tapping, is one-half one man's time, when melting 1 ton in 24 hr.

The furnace was constructed and put into operation by the regular cyanide-plant crew, without the aid of special electricians. The operation is so simple as to require no special training. Although the operators were unaccustomed to handling electrical equipment, no trouble has been experienced from electrical shocks, since the bottom of the furnace acts as the lower electrode, or grounded circuit.

The advantages of the electric furnace compared to the blast furnace for melting high-grade gold slags are: A saving in mechanical loss of gold in flue dust, because the melting is done in a quiet neutral atmosphere, instead of in a rising blast of air; the obtaining of a lower-grade slag, free from shot, by reason of the quieter melting action and the higher temperature obtainable, making a more fluid slag; the nicety of regulation of the melting temperature; the benefit to the general health of the operators.

Chemical Engineering

Hydrogen Manufacture.—In an article on the manuture of hydrogen for the inflation of baloons, in *Revue générale des Sciences* of June 15, 1915, Mr. A. FOURNIOLS gives a history of the development of hydrogen-generating processes and describes some methods of producing this gas for inflating purposes.

The problem of transportation presented the greatest difficulties in connection with the utilization of the hydrogen gas set free in large quantities as a by-product in electrolytic, caustic and chlorine plants. In compressing and transporting this hydrogen a problem presented itself in the great weight which must be moved to get a small amount of hydrogen to a certain point. This gave rise to the development of other processes in which not the hydrogen but the apparatus and material for its production were placed on carriages. A few of these processes are the hydrolitic or calcium hydride process, the silicon and ferro-silicon process, and the coke and oil process used in Germany. The calcium hydride process depends upon the reaction $CaH_2 + 2H_2O = Ca(OH)_2 + 2H_2$. The apparatus consists of a generator, water reservoir, purifier, and various other minor attachments, mounted on a carriage. A comparison of the price of transporting gas in this way with the compressed hydrogen method follows (1 franc = about 20 cents):

Cylinders with Compressed Hydrogen	Francs	Hydrolytic	Francs
8000 tubes at 80 fr.	640,000	48 tons at 5 fr. per kg.	240,000
50,000 cubic meters of hydrogen at 0.40 fr.	20,000	Apparatus for generating	40,000
Carriers for tubes	60,000	Carriers for reagents	4,000
12 carriages of 3 tons	240,000	2 carriages of 3 tons	40,000
	960,000		324,000

This table is only intended to compare transportation cost, as the hydrolytic process is expensive as a stationary means of production.

The silicon process consists in decomposing a compound of silicon by a concentrated soda solution. The apparatus required is a generator containing the soda, a spraying apparatus containing ferrosilicon, a washer and dryer for the gas. The standard stationary apparatus furnishes 1500 cubic meters per hour, while the movable apparatus, using two wagons, furnishes only 400 cubic meters per hour. The latest German process used for both lighting and inflating purposes, using coke and oil, is also capable of being transported ready for generating purposes. For a description of this process and other information on hydrogen production see this journal, Vol. IX, page 157.

Glass Melting.—Methods of manufacturing glass, descriptions of furnaces and the properties of glass in the molten condition are discussed in an article by HUGO KNOBLAUCH, in *Zeitschrift für angewandte Chemie,* June 22, 1915. The characteristics of molten glass mixtures are illustrated by drawings of cross-sections of crucibles containing characteristic charges. The fact that the temperature at which our very best fireproof clay weakens lies near the temperature needed to produce a good melt is shown to make the pyrometer very useful in glass making.

Investigation of Fusible Tin Boiler Plugs.—The failure and deterioriation of fusible tin boiler plugs in service has been investigated by G. K. BURGESS and P. D. MERICA of the Bureau of Standards. The complete investigation will be published in a Bulletin shortly to be issued by the Bureau of Standards. In some cases such plugs have failed to melt and so give warning of dangerous boiler conditions, and investigation has shown that the tin filling in these cases had become oxidized to tin oxide (SnO_2), which has a melting point above 1600 deg. C. (2900 deg. Fahr.). About 1050 plugs, of which 100 were plugs which had been in service, were obtained through the courtesy of the Steamboat-Inspection Service, Department of Commerce, and subjected to examination. This included inspection of design and construction, condition and purity of the tin filling, and in the case of the used plugs their classification according to the type of deterioration undergone by them in service.

One pronounced and dangerous type of deterioration is the oxidation of the tin along the grain boundaries by which is formed a network of oxide throughout the tin. The plugs showing deterioration of this type all came from the same manufacturer and contained zinc in amounts varying from 0.3 to 4 per cent. It is shown that this type of oxidation is due to the presence of this zinc. The latter metal is not soluble in the solid state in tin, and when a tin with small amounts of zinc is heated as in a boiler to about 180 deg. C (340 deg. Fahr.) this zinc coalesces as a network enveloping the tin crystals or grains. The boiler water, particularly if it contains alkali, will attack the zinc, eating its way into the alloy along the zinc network, and finally form the oxide network described.

Lead and zinc are found to be the principal impurities in tin plug fillings, and since all "failed" plugs contained these or other impurities the conclusion is reached that if these impurities are eliminated by strict specifications and inspection, which will allow only admittedly superior qualities of tin such as Banca and some others, the danger of failures of these plugs will no longer exist. In order to test quickly the purity of a tin sample a determination of its freezing point may be made. This can be done conveniently with two or three grams of the sample, and requires only inexpensive apparatus, including a high resistance millivoltmeter and a copper-constantan thermo-couple.

Electroanalysis and Electrodeposition

Procedure in Electroanalysis.—Two papers by E. P. SCHOCH presented at the New Orleans meeting of the American Chemical Society are interesting. They are abstracted in *Science* of July 16. The first of these, a paper by E. P. Schoch and Denton J. Brown, deals with a "systematic, rapid, electroanalytical procedure for the separation and determination of silver, arsenic, copper, bismuth, antimony, tin, lead, and cadmium.

In earlier work the authors have shown that copper, tin, lead, bismuth, and antimony can be determined accurately by electrodeposition out of acidified chloride electrolytes which contain suitable reducing agents such as hydroxylamine or formalin. They have found since that copper, bismuth, and antimony can be deposited simultaneously, and can be separated from tin and lead; that tin and lead can be deposited simultaneously and separated from cadmium; that copper or bismuth can be separated from antimony by dissolving alloys of these metals in nitric acid plus tartaric acid and electrolyzing the solutions with a limited cathode potential; that bismuth phosphate can be precipitated quantitatively out of the same solution; that tin may be separated completely from lead by dissolving an alloy of these two metals in nitric acid plus potassium nitrate, and that silver in silver chloride may be determined by dissolving the latter in ammonia, adding ammonium nitrate and electrolyzing.

These facts are all combined in the following systematic procedure for the rapid electroanalytical determination of all the common metals the potentials of which are more noble than that of cadmium.

(A) Dissolve sample in hydrochloric acid or in aqua regia; an insoluble residue—silver chloride—is dissolved in ammonia plus ammonium nitrate, and the silver determined electrolytically.

(B) Treat solution A with hydroxylamine—mercury, gold and platinum will be precipitated and can be determined by well-known methods.

(C) Out of filtrate B remove arsenic by distillation with hydrochloric acid, and determine arsenic iodometrically.

(D) Electrolyze retort residue C—copper, antimony and bismuth will be deposited with a cathode potential limited to 0.45 volts (against the normal calomel electrode).

(E) Dissolve metal deposit ~~B~~ D in nitric acid plus tartaric acid, and precipitate bismuth as bismuth phosphate.

(F) Electrolyze filtrate E with a limited cathode potential—copper alone will be deposited. Antimony is obtained by difference.

(G) Electrolyze residue D with a cathode potential limited to 0.7 volt against the normal calomel electrode—tin and lead will be deposited. Treat the deposit with nitric acid plus potassium nitrate; the solution contains all the lead, and this metal may be deposited as lead peroxide, or the residue of tin oxide may be dissolved in hydrochloric acid plus hydroxylamine and the tin determined by electrolysis.

(H) Electrolyze residue G to obtain cadmium or other metals.

The second paper, by E. P. SCHOCH and W. A. FELSING, deals with the influence of the potassium ion upon the **potential of the ferrocyanide-ferricyanide electrode.**

The potential of the ferrocyanide-ferricyanide electrode is made more noble by the addition of potassium salts to the electrolyte, but the amount of this change in potential is much greater than the amount calculated from the change in the ratio of ferrocyanide to ferricyanide ions when the concentrations of the latter are calculated from the conductivity ratio and with the aid of the rule of mixtures as set forth by Sherrill. It was suggested by Lewis that this extra effect may be due to the potassium ion taking part in the pole reaction. Thus, with the undissociated salts, the reaction would be $K_3Fe(CN)_6$ plus K-ion plus one electron gives $K_4Fe(CN)_6$, and it has been shown recently by Mueller that with concentrations of potassium ion ranging from 0.2 normal to 0.8 normal the amount of change in potential corresponds to the amount of change in the potassium ion if the concentration relations of the other substances remain constant. Since the latter is not likely to be true, and since the potassium ion shows the

same influence even in the most dilute solutions tried, the authors sought to ascertain whether or not concentration influence of the potassium ion is constant with a particular power of its concentration. This was found to be the case with the 0.75 power of the potassium ion concentration, and if the ferrocyanide and the ferricyanide ion concentrations are calculated from the conductivity ratio and the rule of mixtures. The various mixtures tried present a range of total potassium ion concentration from 7.8 millimol to 395 millimol per liter. In some mixtures the potassium ion was derived wholly from the iron cyanides, in others almost wholly from potassium chloride, and in others still partly from both sources. The different potentials thus reduced to unit concentrations present a maximum range of 8 millivolts with this large variation of concentrations, and hence the result may be considered to be constant. Furthermore, it is likely that on reptition, measurements will be obtained which will show considerably less variation.

Since the calculation of the above potentials involve the general dilution law of strong electrolytes and the rule of mixtures, it was desirable to test these calculations in some way, hence the conductivities of these mixtures were measured and compared with their calculated values. When allowance is made for the influence of the viscosities of the solutions, then the observed and the calculated conductivities agree to 1 per cent and less.

The work is now being repeated with calcium salts in place of potassium salts. Although the immediate result of this work is the establishing of an empiric relation between concentrations and pole potentials, yet it is likely that the results will throw some light on the manner of ionization of salts with polyvalent ions—particularly because other electrodes, such as the thallous-thallic, the ferrous-ferric and the mercurous-mercuric, show similar relations.

Recent Chemical and Metallurgical Patents

Gold

Vacuum Filter.—A modification of the revolving vacuum filter is shown in Fig. 1, being the patented invention of Mr. HENRY B. FABER of New York City. It consists of a skeleton wheel structure in which are mounted filter pockets 10 which are connected, through a suitable valve in the hub, with a source of vacuum. In operation the wheel is revolved slowly and each pocket

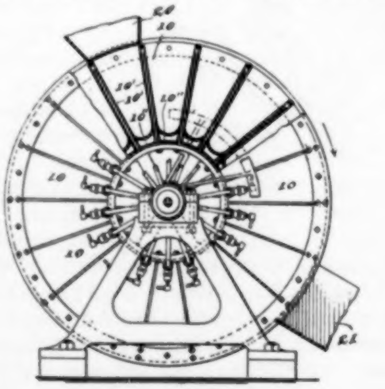


FIG. 1—FILTER

receives a charge from the hopper 20. Being under vacuum, the fluid is withdrawn from the pocket and the solid material forms a cake on the filter surface. As the filter continues to revolve, the cake is discharged by gravity at a predetermined point, as in the hopper 21. As no provision is made for washing the cake, the machine is adapted for use only as a dewaterer and not in cases where complete displacement of the liquor from the solid is required. (1,133,944, March 30, 1915.)

Copper and Zinc

Hydrometallurgy of Copper Ores.—In a patent granted to Mr. N. V. HYBINETTE of Christiansand, Norway, the inventor discloses his process for roasting copper ores and extracting the copper therefrom. An improvement in the ordinary roasting process is claimed in the addition of a quantity of sodium sulphate to the ore. The effect is to form double sulphate of sodium and copper which is decomposed only at temperatures higher than those prevailing in the roasting furnace. The addition of from 2 per cent to 5 per cent sodium sulphate forms a fusible double sulphate which has the property of dissolving sulphides and which forms a spongy mass easily leached with dilute sulphuric acid. The solution resulting from subsequent electrolysis contains sulphuric acid and ferric sulphate and is used for further leaching. Ultimately this solution will contain so much sodium sulphate that it can no longer be used for leaching. When this point has been reached and the solution contains about 450 gr. sodium sulphate per litre, the solution itself is added to the ore in order to supply the sodium sulphate for roasting. The iron salt in solution is decomposed in the roasting furnace, exerting a solvent effect on copper sulphide remaining in the ore as a result of incomplete roasting. (1,140,682, May 25, 1915.)

Electrolysis of Copper Solutions.—In the electrolytic reduction of copper solutions, the presence of certain compounds of metals other than copper exercises a solvent effect on the deposited metal, which is often detrimental. Thus ferric compounds in an electrolyte would act to dissolve deposited copper. Mr. LAWRENCE ADDICKS of Douglas, Ariz., has discovered that the presence in solution of a quantity of aluminum sulphate retards the corrosion rate at the cathode to a small proportion of the quantity of copper deposited per unit of time at the current density used. As a practical illustration of conditions suitable for good work, the inventor gives the following: A solution containing copper, iron and aluminum sulphates, containing 3 per cent copper, 3 per cent ferrous iron and 3 per cent alumina, some free sulphuric acid to prevent the formation of basic salts. This is electrolyzed with a current density of 13.5 amp. per square feet, at a temperature of 115 deg. Fahr., and with a circulation sufficient to keep the average concentration of ferric iron at about 0.25 per cent. Under such conditions a cathode deposit equivalent to from 70 per cent to 90 per cent of the theoretical can be obtained. (1,138,921, May 11, 1915.)

Metallurgical Furnaces

Reducing Aluminium Sulphate to Alumina.—A furnace adapted to the preparation of alumina suitable for electrolytic reduction to aluminium is shown in Fig. 2,

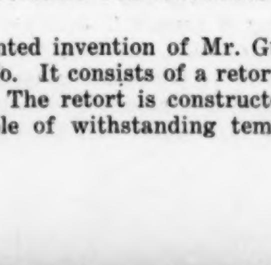


FIG. 2—FURNACE FOR PRODUCING ALUMINA

being the patented invention of Mr. GUSTAVE SCHWAN of St. Louis, Mo. It consists of a retort 11 arranged in a furnace 12. The retort is constructed of refractory material capable of withstanding temperatures up to

1200 deg. C., and is separate from the furnace. Inside measurements of the retort are 8 in. wide and 8 ft. or more in height. The furnace is heated by gas which enters by pipes 13 which convey the gas to the upper portion of the combustion chamber 14. Preheated air is conveyed to the same point by pipes 15. The Products of combustion flow through passages 16 to a flue 17. The material to be treated may be fed into the retort from a hopper 18 by means of a feeding device 19. The gaseous products from the retort pass out through pipe 20, and the solid product is removed by a screw arranged at 21. (1,132,738, March 23, 1915.)

Roasting Furnace.—A method of heating the charge in a roasting furnace of the superposed-hearth type, without subjecting the rabbles to excessive heat, is patented by Mr. Utley Wedge of Ardmore, Pa. Gas, oil or electric current may be used as the heating medium. The rabble arms and means for heating, either oil or gas burners or electric heaters, are all attached to the same central rotating shaft, but are disposed at right angles with each other, so that the rabbles are at some distance on the hearth from the heaters. (1,133,829, March 30, 1915.)

Iron

Process for Dephosphorizing Pig Iron.—According to a method of removing the phosphorous from pig iron, patented by Amand Francois Pasquier of Dijon, France, iron oxide and lime in a finely pulverized condition are blown through the tuyeres by the air blast. The iron oxide is claimed to rapidly transform the phosphorus into phosphoric acid, which combines with the lime and passes into the slag as calcium phosphate. The phosphorus is thus eliminated without the usual overblasting or recarburation. Instead of lime, magnesia, dolomite, or similar bases could be used and the oxide of iron might be added in the form of hammer scale or force scale (1,145,506, July 6, 1915).

Aluminium

Treatment of Surfaces of Aluminium for Plating.—A process for preparing aluminium surfaces for plating is patented by Francois Auguste Roux of Paris, France, and assigned to Société L'Aluminium Français. In this process the aluminium surface is first cleansed by any common method, then it is rinsed and immersed in a dilute acid or alkaline hydrate solution to which 1 per cent of tin chloride is added. This gives a coating of tin on the surface. The surface is then rinsed and immersed into hot saturated solution of ammonia alum. This is claimed to cause any inclosed hydrogen to escape and to prevent the oxidation of aluminium which has been the greatest hindrance to aluminium plating. It also gives tenacity to the tin deposit. The surface is then rinsed and dipped into dilute sulphuric or nitric acid and finally placed in the plating bath (1,140,000, June 22, 1915).

Process of Plating Aluminium.—Another process of plating aluminium is patented by Joseph A. Hall of New Britain, Conn. In this process the aluminium is first cleansed in the usual manner, then given a bright dip in a solution made up of 2 parts nitric acid and 1 part oil of vitriol. This is to remove iron, which is claimed to be found usually on the surface of commercial aluminium and which is believed to hinder successful plating. The surface is then electroplated with zinc for a few seconds and is then ready to receive the plate of brass, copper or silver. In the case of nickel plating a preliminary coating of copper is first given for twenty to thirty minutes and then the nickel is applied. The process is claimed to be particularly applicable to plating the material used for making die castings, which is high in aluminium (1,147,718, July 27, 1915).

Oil

Dehydrating Petroleum Oil.—Apparatus for the separation of water and petroleum oil when mixed in the form of emulsion is described in three patents issued to Robert E. Laird and Joseph H. Raney of Taft, Cal. A general outline of the process is as follows: In the treater, Fig. 3, the emulsion enters at 23 into chamber 16, which surrounds the outer electrodes 21. It is heated here by steam coils to any desired temperature, and then passes through openings 22 into chamber 17, and upwardly between the outer electrodes 21 and inner electrodes 19. When an alternating current is impressed on the electrodes, it tends to change the trapped water into free water and to coalesce the free water. The emulsion flowing upward is fairly free from water at the top and no extra insulation is required at the surface. The freed oil passes upward into pan 12 and down through pipe 231 into another final separator. The electrical apparatus, which is a distinct feature of the invention, consists of a condenser placed across the electrode terminals, and a "distributer" which is so adjusted that only the peaks of the alternating wave are utilized, which during the other parts of each period the current charges the condenser which subsequently discharges through the oil along with the high-voltage current represented by the peaks. This gives maximum power economy. Means are also provided to allow escape of gases and to prevent combustion. The process is described fully in *San Joaquin Light and Power Magazine* for May, 1915, where it is said to be in successful use on the property of the Traders' Oil Company in the Midway Field (1,142,759, 1,142,760 and 1,142,861, June 8, 1915).

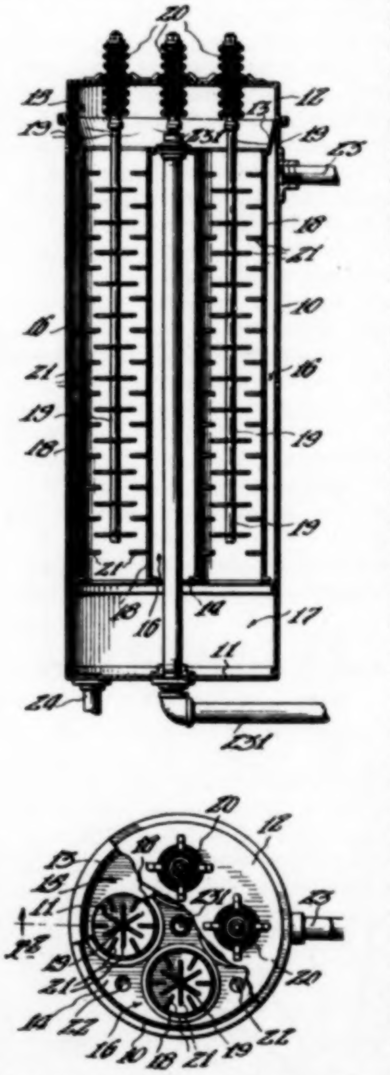


FIG. 3—ELECTRIC APPARATUS FOR DEHYDRATING OIL

An aluminium alloy, patented by Alfred Wilm, of Schlachtensee, near Berlin, Germany, contains about 95.5 per cent aluminium, 0.5 per cent magnesium, 3 per cent copper and 1 per cent manganese.

The inventor claims to have discovered an alloy that retains the advantage of aluminium as to light weight, in addition to other advantages which are not possessed by that metal.

Thus it is claimed that this alloy can be bored, drilled, planed, filed and ground successfully.

Callow Pneumatic Process of Flotation

The diagram, Fig. 1, indicates the various elements which compose the scheme.

A is an agitator operating by compressed air for the purpose of mixing or emulsifying the oil, the air and the water. The same type of apparatus as is in common use in cyanide works. In cases where the oil or frothing agent can be fed into a crushing machine or tube mill, this agitator or Pachuca tank can be dispensed with and the ore fed direct from tube mill into the separatory cell.

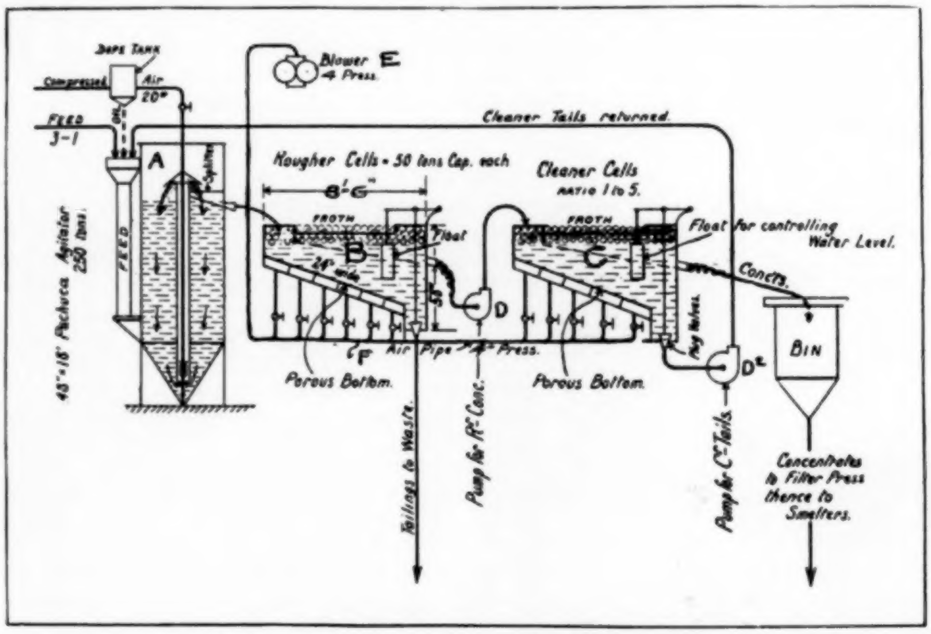


FIG. 1—CALLOW PNEUMATIC FLOTATION PROCESS

Separatory Cell

B is the initial or roughing separatory cell; it consists of a tank about 9 ft. long over all and 24 in. wide, with bottom inclined at from 2 to 3 in. of fall per foot; it is 15 in. deep at the shallow end and 37 in. deep at the deepest end. It may be built of either steel or wood, preferably wood.

The bottom of the tank consists of a porous medium made of four thicknesses of loosely woven canvas-twill properly supported by a backing of perforated metal to prevent its bulging when under air pressure. Through this porous medium, compressed air at from 4 to 6 lb. pressure is forced by the blower *E*. Porous brick or any other ceramic material may be used that will give the necessary fine subdivision to the air. Some of these have been tried out, but for practical and mechanical reasons the loosely woven canvas-twill seems to better serve all purposes than anything else and has been adopted as a standard porous bottom construction.

The space underneath this porous medium or bottom is subdivided into eight compartments, each connected by an individual pipe and valve with the main air pipe *F*. By this means the air pressure to each compartment can be regulated (by throttling the valve) to correspond to the varying hydraulic head within the tank so as to discharge a uniform amount of air throughout the length of the bottom and maintain a uniform agitation of the contents. The amount of air required is from 6 to 8 cu. ft. free air per minute at from 4 to 6 lb. pressure per square foot of porous medium. A 500-ton plant will require about 30 hp. to operate compressor, blower and pumps.

Each longitudinal edge of the tank is provided with a lip and an overflow gutter for the reception of the froth to be discharged. The lower end of the tank is furnished with a spigot discharge fitted with a plug valve, operated by a float, for the purpose of maintaining a uniform water level within the tank and thus in turn maintaining a uniform and constant discharge of froth under all the varying conditions of feed supply incident to practical milling operations. The water level may, of course, be varied, but is usually maintained at about 10 to 12 in. below the level of the overflow lips. The tailings are discharged through the spigot and the frothy concentrates are conveyed by means of the side gutters to the pump *D* and thence to the cleaner separatory cell marked *C*. This cleaner cell is a machine of exactly the same construction as the rougher. In operation, however, it is usually run with a lower air pressure than that used on the rougher; the tailings from the cleaner are pumped by *D*2 back into the original feed and so maintain a closed circuit on this portion of the feed.

The concentrates from the cleaner are the shipping or finished concentrates. Pump *D* can be eliminated if desirable by setting the cleaner at a lower elevation and conveying the rougher froth to it by gravity.

FIG. 2—500-TON INSTALLATION CALLOW PNEUMATIC FLOTATION MACHINES, NATIONAL COPPER MINING CO., MULLAN, IDAHO

Usually one cleaner will be sufficient to take care of four roughers. The froth formation and pulp density will now be considered.

Froth Formation

The froth is generated as the result of injecting the finely divided air into the bottom of the already emulsified pulp, and it continues to form and to overflow so long as it is furnished with pulp of the proper consistency, properly mixed, and with the right quantity and kind of oil or frothing agent. Measured from the water level within the tank, the froth produced may be from 14 to 16 in. in depth or thickness, and according to the kind of ore, kind and quantity of oil introduced will be more or less voluminous, coarse or fine grained, dry or watery, all of these conditions being adjusted by the regulation of the kind or quantity of oil and the quantity of air injected.

On some ores, rich in sulphides, and where a comparatively low grade concentrate will suffice, the cleaner may not be necessary, but on low grade ores having a high ratio of concentration and where a concentrate of extreme cleanness and of maximum grade is required, a cleaner is desirable.

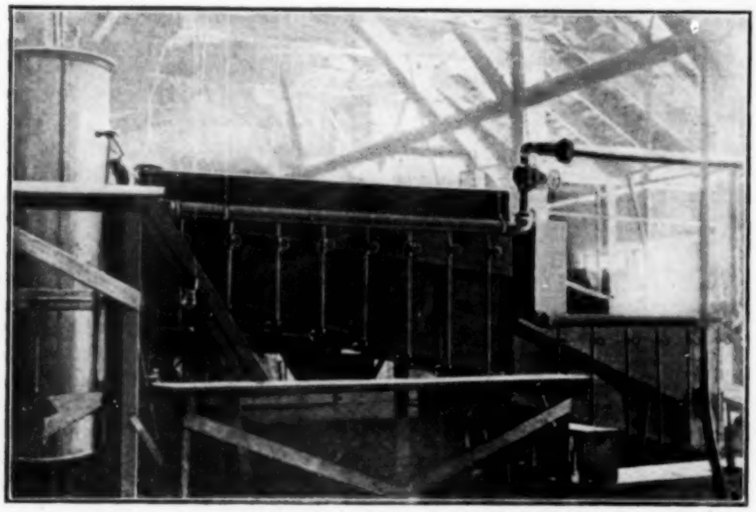


FIG. 3—30-TON EXPERIMENTAL UNIT, CALLOW PNEUMATIC FLOTATION MACHINES, DALY-JUDGE MILL, PARK CITY, UTAH

Pulp Density

The pulp to be treated may be of varying density from 2½ water to 1 ore, up to 6 or 7 to 1. For a mixture of sand and slime the former ratio is preferable, but for a pure slime mixture (minus 200 mesh) a larger proportion of water is allowable. The particular density is not a matter of so much importance as that the supply of pulp shall be uniform as to its density, since each variation in the density of the pulp requires a readjustment of the oil supply, the quantity of oil increasing in proportion to the increased volume of the pulp independent of the solid contents.

Oils

The oils used may be broadly divided into "frothers" and "collectors." The pine oils are good frothers and coal tar and its various subdivisions are good collectors. On some ores, crude pine-tar will in itself combine both the property of frothing and collecting. On others this may have to be enriched by the addition of some one of its more volatile constituents such as refined pine oil, turpentine or wood creosote.

Generally speaking the coal-tar products are poor frothers, and to get a sufficient volume of froth to insure a high recovery it is often necessary to add refined pine oil, creosote, etc. At Inspiration, for instance, the mixture is 85 per cent crude coal-tar, 15 per cent light oil or creosote, 5 per cent pine oil. At Daly-Judge, 40 per cent crude coal-tar, 40 per cent creosote, 20 per cent pine oil. In the Coeur d'Alenes, on zinc ore, straight wood creosote; on the National copper ore plain turpentine will work, but pine oil is better. At Inspiration it required from 1½ to 2 lb. of the mixture per ton of ore; at Daly-Judge 1 to 1½ lb. and at the National 3/10 of a pound of oil is sufficient. The proper kind or kinds of oil and the quantity requisite can only be determined at present by tentative experiment; so far there is no scientific way known.

Character of Froth

The nature of the froth made by the pneumatic process has the distinctive characteristic of being unstable or ephemeral; that is, it quickly dies when removed from the action of the injected air. The bubbles composing the froth being generated under a hydraulic pressure varying from 15 to 37 in., on rising above the water and to the froth level, burst by reason of the lower surrounding atmospheric pressure. On bursting they release the mineral coating them, but this in turn is caught up by those bubbles immediately following behind. The instability or stability of the bubbles will depend upon the oil used and the nature of the ore gangue. Pine oil makes a very brittle froth which dies immediately on arriving at the surface. Creosote and light oil make a very elastic envelope which at times will expand into bubbles 3 or 4 in. in diameter before bursting. The pine oil bubbles will rarely be over ¼ or ½ in. in diameter. Castor oil, olive oil, candle makers' oil (oleic acid), palm oil, sperm oil and other oils of a lubricating nature have in general been replaced by oils more or less soluble or miscible in water, such as turpentine, pine oil, eucalyptus oil and all the other coal and woodtar distillations. The very volatile oils such as naphtha, gasoline, ether and alcohol seem to serve very little purpose except as means for making the pitchy ingredients of coal and wood-tars more soluble or miscible.

With the present knowledge of the subject it is impossible to state by a visual examination or an analysis of the ore, whether or no it can be successfully treated by flotation. Only properly conducted tests can determine this. The General Engineering Company of 159 Pierpoint Street, Salt Lake City, Utah, has equipped its testing plant for conducting the necessary preliminary tests for which an average 100 to 150-lb. sample will generally suffice. Should the preliminary tests show encouraging results, it is advisable to follow them up by the installation of a 20 or 30-ton experimental unit in the plant, or where there is no plant in existence a 5-ton sample can be sent to the General Engineering Company for further and final investigation.

Materials of engineering construction will receive special attention in the proceedings and discussion of the International Engineering Congress to be held in San Francisco next September. The field will be treated under 18 or more topics, covering: Timber resources; preservative methods; brick and clay products in general; life of concrete structures; aggregates for concrete; water proofing; volume changes in concrete; world's supply of iron; life of iron and steel structures; special steels; status of copper and world's supply; alloys; aluminum; testing of metals, of full sized members, and of structures.

Magnetic Separation of Zinc-Iron Sulphide Ores

Some tests recently conducted by the Campbell Magnetic Separating Company of Boston, Mass., in its plant at Cuba City, Wis., on the separation of the sulphides of iron and zinc are described in a pamphlet issued by the above company. The process consists in roasting the ore in a special kiln for from three to five minutes, then feeding it over a table in a thin layer on which it is agitated and exposed to the magnet. The

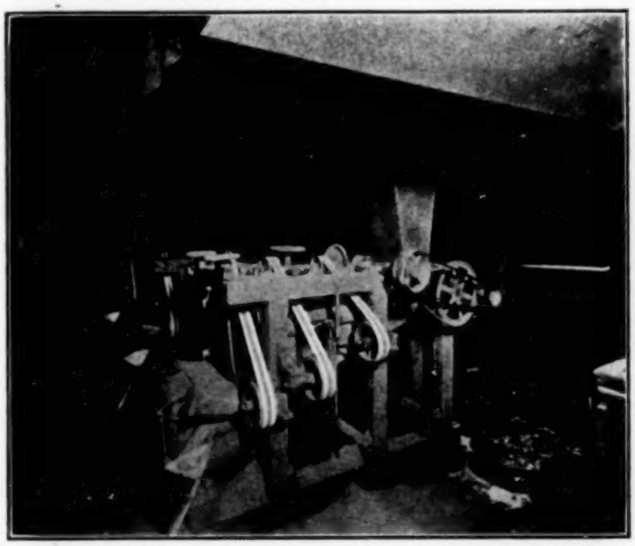


FIG. 1—VIEW OF EIGHT CAMPBELL MAGNETIC SEPARATORS INSTALLED IN THE COMPANY'S PLANT IN CUBA CITY, WIS.

iron is removed and the zinc flows on over the end of the table.

The following figures give the results of a seven-day test made upon the plant at Cuba City by Mr. Charles L. Constant of New York City.

Assay of raw ore:

Moisture	3.75 per cent
Zinc	16.50 per cent
Iron	33.00 per cent
Sulphur	42.49 per cent
Lime	1.95 per cent

Assay after roasting:

Zinc	19.20 per cent
Iron	37.80 per cent
Sulphur	35.30 per cent
Lime	1.12 per cent

Zinc concentrate after separating:

Zinc	60.75 per cent
Iron	2.05 per cent
Sulphur	29.95 per cent
Lime	2.00 per cent

Iron concentrate after separating:

Zinc	1.25 per cent
Iron	53.30 per cent
Sulphur	37.35 per cent
Lime	1.05 per cent

Further information is taken from the records of the Linden Zinc Co., Linden, Wis., who are using the Campbell system. Its average recovery of metallic zinc for 1914 was 95.4 per cent, the zinc in the iron varying between 0.60 per cent to 4 per cent and the average percentage of sulphur in the iron being about 35 per cent. Low operating costs and the small amount of labor required are other advantages claimed for this process and also its adaptability to the lowest-grade zinc ores, and table middlings and treatment of chalcopyrite.

At **St. Louis University** the gold medal for the best essay on the "nitrogen problem" has been awarded to Mr. Sylvester Flottemesh.

Titanium

"Geology of the Titanium and Apatite Deposits of Virginia," by THOMAS LEONARD WATSON and STEPHEN TABER, is the title of Bulletin 3A of the Virginia Geological Survey. This beautifully illustrated description of exhaustive field work and laboratory investigation on the Virginia deposits is without doubt the most complete work yet published on titanium ores. It also includes a large amount of general information on titanium which should make the volume one of great value to those interested in this subject. The commercial value of some of the Virginia deposits makes the discussion not only of scientific but also of economic importance.

The first chapter of the bulletin discusses the history, chemistry and ores of titanium with their distribution and occurrence, including a complete table of titanium minerals. The second chapter describes the occurrence and geographic distribution of rutile with descriptions of the areas in which it is found. This includes foreign countries, the principal ones being Canada, Norway and South Australia. Photomicrographs of specimens from Australia and Norway show the nature of these rutile-bearing rocks.

Chapter III begins the main portion of the volume, giving the results of the field and laboratory work in Virginia on the ore deposits of the Amherst-Nelson counties region. Topographical maps, photographs and photomicrographs interspersed throughout the text explain the rock formations, and analyses are given to show the chemical composition. "The region is shown to be a comagmatic area of unusual scientific interest, many of the rock-types of which are new and described in detail for the first time." This is the most important district commercially and its description takes up about two-thirds of the volume. Included in this chapter are also individual descriptions of mining properties in this district, the principal mine being that of the American Rutile Company. This is followed by a description of the general petrology of this region.

The fourth chapter discusses the ilmenite-apatite deposits in Roanoke County. These are also commercially important, as are those which were recently discovered in Goochland and Hanover counties and described in Chapter V. Chapters VI and VII describe the occurrence of rutile in Charlotte and Buckingham counties, in which the deposits are of scientific interest only. In the last two chapters economic considerations are discussed, mining methods are suggested and possible by-products mentioned. It is stated that the future of rutile mining in Virginia looks very encouraging as there is practically an unlimited supply of very pure rutile in the Amherst-Nelson counties area, and with the prospecting in the other districts and the development of new uses for titanium an increasing demand is expected which ought to stimulate production.

The utilization of heat from slag, under the Vautin and Johnson patents, is described in a booklet issued by Slag Power, Ltd., Salisbury House, London, England. The method of operation is illustrated and described, and the results of experiments are given showing the available heat that may be obtained from copper and iron slags. Tests indicate that 1000 kilos of copper slag contain from 318 to 350 calories of available heat, and upwards of 500 kilos of water have been evaporated per 1000 kilos of slag. In the case of iron slag the available heat per 1000 kilos is 550 calories, and upwards of 740 kilos of water have been evaporated per 1000 kilos of slag.

National Exposition of Chemical Industries

The opening of America's first National Exposition of Chemical Industries on Monday, Sept. 20, is looked forward to with great interest, as it is an event which cannot fail to be far reaching in its results. It will bring into closer contact than ever before the manufacturers, financiers, dealers and consumers. Elaborate exhibits are arranged, many of them working units, giving visitors the opportunity of seeing the processes in actual work. The character of the exhibitors assures the success of the undertaking.

An invitation has been extended by the advisory committee to President Wilson to be present and participate in the opening of the exposition.

Among the institutions which have co-operated to make this exposition a success are the American Chemical Society, American Electrochemical Society, American Institute of Mining Engineers, American Institute of Electrical Engineers, American Pulp and Paper Associations' Technical Section, and the Bureau of Commercial Economics. Following is an incomplete program which will have numerous other papers and addresses added:

Monday, Sept. 20

Opening day.

Tuesday, Sept. 21

D. P. Pierce (Barber Asphalt Company), "Work with the Ultra Microscope."

Howard H. Gross (president Tariff Commission League) will lead a discussion on the tariff question in which other members of the league will participate.

R. S. Frinck (president Frinck Pyrometer Company), "The Relation of Chemistry and Mechanical Manipulation to the Evolution of the Glass Industry."

Harrington Emerson (the Emerson Company), "Efficiency."

MEETING OF THE NEW YORK SECTION OF THE AMERICAN ELECTROCHEMICAL SOCIETY

Wednesday, Sept. 22

Thomas H. Norton (U. S. Department of Commerce), "Foreign Markets for American Chemicals."

F. W. Keough (president National Association of Manufacturers), "Accident Prevention in the Chemical Industries."

Welding Ring (president American Exporters' Association), "Transportation and Shipping Facilities with Foreign Countries."

I. F. Stone (president National Aniline & Chemical Company), "The Aniline Dye Situation."

J. L. Lightner (Hershey Chocolate Company), "The Manufacture of Chocolate."

Thursday, Sept. 23

J. L. Taylor (U. S. Bureau of Mines), "Explosives."

H. A. Huston (German Kali. Co.), "Potash."

Linn Bradley (the Research Corporation), "Solution of Smoke, Dust and Fume Nuisances by Electrical Precipitation."

Percy Wilson (secretary Association of American Portland Cement Manufacturers), "The History of Cement."

MEETING OF THE AMERICAN PAPER AND PULP ASSOCIATION (TECHNICAL SECTION)

Friday, Sept. 24

S. P. Sadtler (S. P. Sadtler & Sons), "American Contributions to Industrial Chemistry."

W. D. Coolidge (General Electric Company), "The X-Ray."

JOINT MEETING OF THE NEW YORK SECTION AMERICAN CHEMICAL SOCIETY AND THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

Saturday, Sept. 25

John Barrett (director Pan-American Union), "South American Opportunities."

Geo. Frank Lord (DuPont DeNemours Powder Company), "Farming with Dynamite."

G. B. Heckel (New Jersey Zinc Company), "Zinc."

A motion-picture program has been arranged for by the Bureau of Commercial Economics at Washington. This will include various manufacturing processes, mining industries, uses of electricity, and general factory management, and should prove an exceedingly interesting and instructive feature. Many of the exhibitors will also have speakers in the auditorium, who will lecture and display by motion and slide pictures the work of their respective companies.

This lecture and picture program will be announced from day to day on the exposition bulletin boards.

Under the auspices of the Bureau of Foreign and Domestic Commerce, some eight bureaus in the Departments of Commerce, Interior and Agriculture are now arranging noteworthy and instructive exhibits, each of which will be typical and demonstrative of the work of that bureau.

Among the exhibitors at this exposition are the following:

Abbé Engineering Co.
American Hard Rubber Co.
American Chemical Society.
American Bitumastic Enamels Co.
Automatic Weighing Machine Co.
J. T. Baker Chemical Co.
Brown Instrument Co.
W. Beckers Aniline & Chemical Works, Inc.
Bethlehem Foundry & Machine Co.
Buffalo Foundry & Machine Co.
Boonton Rubber Mfg. Co.
Christian Becker.
Condensite Co. of America.
Chemical Process Co.
Chadwick Boston Lead Co.
Department of Commerce, Washington, D. C.
J. P. Devine Co.
Driver-Harris Wire Co.
DuPont DeNemours Powder Co.
Duriron Castings Co.
Dorr-Cyanide Machine Co.
Detroit Range Boiler Co.
Thos. A. Edison.
Elyria Enameled Products Co.
Eimer & Amend.
Fairview Fluorspar & Lead Co.
General Bakelite Co.
General Chemical Co.
Gerdes & Co.
Glens Falls Machine Co.
Emil Greiner & Co.
Ranovia Chemical & Mfg. Co.
Heller & Merz.
Huyck & Sons, F. C.
Huff Electrostatic Co.
International Instrument Co.
Kieselguhr Co. of Amer.
Koven & Bro., L. O.
Lead Lined Iron Pipe Co.
Lenz & Nauman (Scientific Specialties Co.).
Lungwitz, Emil
Metallurgical & Chemical Engineering.
Macbeth-Evans Glass Co.
Moore Filter Co.
Monsanto Chemical Works.
J. L. Mott Iron Works.
National Aniline & Chem. Co.
Norton Co.
Pfaudler Co.
Raritan Copper Works.
Schaefer & Budenberg.
Schaum & Uhlinger, Inc.
Scott & Co., Ernest.
Standard Aniline Products, Inc.
Sweetland Filter Press Co.
Swenson Evaporator Co.
Thwing Instrument Co.
Tolhurst Machine Co.
Troegerlith Tile Co.
United Lead Co.
Valley Iron Works
Wilson-Maeulen Co.
Zaremba Evaporator Co.

Supply of Manganese Ore and Ferromanganese Statistics

From a statement issued by Mr. C. B. Morgan, secretary of the Noble Electric Steel Company of San Francisco, we take the following interesting statistics on manganese ore and ferro-manganese:

MANGANESE ORE

	1913 Tons	1914 Tons	1915 Tons
Imports into the United States	345,090	283,294	......
Average per month	28,757	23,608	......
Imports first half 1915	......	......	52,007
Average per month	......	......	8,700
Imports into England	601,177	479,435	......
Five months ending May, 1915	......	......	107,297
Imports, May, 1915			5,278
Or at a yearly rate of			63,000

FERROMANGANESE

Average imports in the United States, embracing 1910-1914	100,793 tons
Production from imported ore	99,363 tons
Total available yearly supply	200,156 tons
Average imports per month	8,399 tons
Production	8,280 tons
Total available monthly supply	16,679 tons
Imports first half 1915	20,542 tons
Possible production	15,500 tons
Total available supply	36,042 tons
Total available monthly supply	6,000 tons

It will be observed that the first half of 1915 the supply has been 10,000 tons per month less than the average of the preceding five years, or a deficit of 60,000 tons.

Before the war 90 per cent of the importations of ferromanganese came from England, which is now the only foreign source of supply, and as the imports of ore into England are on a diminishing scale, it becomes an interesting question, to what extent England can fill the growing void in the United States. Upon the scale of imports of manganese ore into the United States shown in the first half of this year only a partial relief can be expected from domestic production.

Personal

Mr. **C. W. Badgley**, of the El Paso Smelting Works, has been spending his vacation in Denver, Col.

Mr. **Walter E. Burlingame** announces that the business of E. E. Burlingame & Co., assayers and chemists, will hereafter be conducted under his name at the old location, 1736 Lawrence Street, Denver, Col.

Messrs. **F. G. Cottrell** and **Dorsey A. Lyon**, of the Bureau of Mines, have been in the Coeur d'Alene district, Idaho, preparing for some technical studies in local ore treatment under a co-operative arrangement between the bureau and local operators.

Mr. **Justin H.Haynes** has returned to Denver after four months' professional work near Searchlight, Nevada, and will be engaged in metallurgical work in Colorado.

Dr. **F. W. McNair**, president of the Michigan College of Mines, recently made a trip through Ontario, visiting Cobalt, Porcupine and Sudbury, where he was entertained by alumni of the college.

Mr. **H. C. Parmelee**, Western editor of METALLURGICAL AND CHEMICAL ENGINEERING, has been appointed by the Governor of Colorado as a trustee of the Colorado School of Mines. The other appointees are Mr. **Orvil R. Whitaker** of Denver and Mr. **H. M. Rubey** of Golden.

Mr. **W. H. Staver** is in charge of mining and milling operations on the Suffolk property, Ophir, Col.

Mr. **H. L. Sulman** has been elected president of the Mining & Metallurgical Club, London.

Obituary

In memory of **Albert Plaut**, the late president of Lehn & Fink, and treasurer of The Chemists' Club of New York City, the Board of Trustees of The Chemists' Club has adopted the following minute: The death of our treasurer, Albert Plaut, inflicts on The Chemists' Club and its members a very great loss. His unflinching interest in the club's affairs, his generous helpfulness on every occasion that offered itself, his keen interest in the work of chemists and his encouraging appreciation of these efforts, his sturdy maintenance of what he regarded as right, together with his gracious good fellowship, all endeared him to the large number of us who knew him. And while we record our poignant grief at his passing, we acknowledge both appreciation and pleasure in that ours was the privilege to be associated with one who ordered his life to such good ends and whose friendship was indeed a benediction to those who shared it.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath, Anodes

546,483, September 17, 1895, Henry L. Bridgman, of Blue Island, Illinois.

Relates to anodes for electrolysis and consists of a frame which may be of insulating material, or of lead, copper, or other conductor that is not attacked by the electrolyte. The frame supports a plurality of V-shaped pockets separated at the bottom, and placed one above the other, spaced apart a distance approximately equal to the depth of the pocket. Above the pockets is a hopper, and below a movable board serving as a stop for the anode material supplied to the hopper. A pipe is provided to supply electrolyte to the anode material, to wash out any sludge, also a stirring rod to prevent the anode material from becoming too compact. The kind of anode material used is not described.

553,464, January 21, 1896, Eugene Hermite, of London, England, assignor of two-thirds to Edward James Paterson and Charles Friend Cooper, of same place.

Relates to anodes, and describes securing a network of platinum wires to a glass plate. The plate is drilled with a plurality of holes, all over the plate, and platinum wire is either threaded through the holes, so as to produce as complete a net-work as possible, or insulating studs are inserted in the holes, and the platinum wire supported by the studs. The net-work of wire may be on one side or both sides of the plate.

568,229, September 22, 1896, Henry Blackman, of New York, N. Y.

Relates to anodes for electrolysis of alkali chlorids, preferably for making bleaching liquor, and contains a reference to a copending application which became patent 568,231. The anode consists of an oxid of iron, or a mixture of oxids, bonded with a suitable binding or fluxing material. The material preferred is known as "black slag," a residue from pig-iron furnaces; it is fusible, and may be cast into any desired shape. The

black slag may, if desired, be mixed with magnetite, or other oxids of iron, or pulverized carbon.

568,230, September 22, 1896, Henry Blackman, of New York, N. Y.

Relates to anodes for electrolysis of alkali chlorids and describes making the anode from the mineral "ilmenite" or titanium-iron-oxid. The material is either sawed into shape, as is a block of granite, or may be melted with the aid of a small quantity of fluxing material and cast.

568,231, September 22, 1896, Henry Blackman, of New York, N. Y.

Relates to anodes for electrolysis of alkali chlorids, and describes magnetite and ilmenite, which may be shaped by sawing, melting and casting, or pulverizing and mixing with a binding material such as tar and molasses, pressing into the desired shape and baking.

572,472, December 1, 1896, Hamilton Young Castner, of London, England.

Relates to anodes for electrolytic purposes, and describes heating a piece of gas-retort carbon, eighteen inches long by one inch square cross section to an immeasurable temperature by passing an electric current of about five hundred amperes for a few minutes, the carbon rod being covered by powdered charcoal to protect it from oxidation. After cooling the rod possessed decreased density and increased conductivity, and was less susceptible to chemical action than before treatment.

578,070, March 2, 1897, Albert E. Woolf, of New York, N. Y., assignor to Rosamond Woolf, of same place.

Relates to anodes for electrolysis and describes a sheet of platinum or similar difficultly corrodible metal or alloy, about one one-thousandth of an inch thick, comparatively narrow, and having a length several times its width, secured at one of its longer edges and two short edges to a base metal such as copper, iron, etc.; the base metal serving as the conductor and insulated with glass, enamel, etc. The electrode thus insulated may be safely immersed in an electrolyte and used as an anode at which corrosive gases are liberated.

621,121, March 14, 1899, John T. Morrow, of Great Falls, Montana.

Relates to a supporting means for copper and similar anodes, used in copper-refining. The supporting means consists of folded straps of pure rolled sheet copper having their ends cast into the impure anode. The straps serve as supports and conductors and effect an economy in the amount of copper to be remelted when the anode is consumed.

627,573, June 27, 1899, Charles Cunningham Connor, of Belfast, Ireland.

Relates to anodes for electrolysis and describes uniting pieces of gas-carbon, graphite, coke, etc., together by lead. The carbon blocks of carbon may be drilled, supported in a frame, separated by asbestos washers and lead poured into the drilled holes and washers. Or the carbon blocks may be thrust part way into sand, and a layer of molten lead poured on the sand securing the carbons in such a position that they project equally on each side of the lead layer, the latter serving as the conductor. Or the carbons may be drilled and bolted on the sides of a lead plate having projecting lugs. In each case the lead plate, etc., is insulated with enamel, pitch, etc.

633,056, September 12, 1899, Arthur L. Walker, of Perth Amboy, New Jersey.

Relates to a supporting and connecting means for copper anodes and consists in casting the crude anodes with holes or perforations in the "ears" or lugs, in which supporting bolts or "eyes" may be secured, thereby effecting an economy in the amount of undissolved anode to be recast.

639,811, December 26, 1899, Harry L. Haas, of New York, N. Y., assignor to the Zucker & Levett & Loeb Company, of same place.

Relates to a supporting hook for anodes, which is integral with the anode, and is provided with broad flat square-jointed faces or surfaces by which the anode is suspended, and by which electrical contact is made.

658,891, October 2, 1900, Henry Carmichael, of Malden, Massachusetts, assignor to S. D. Warren & Co., of Boston, Massachusetts.

Relates to an anode consisting of a net-work of platinum wire the wire supported upon and secured to projecting pins of platinum, which in turn pass through and are sealed in the ends of glass tubes, the tubes passing through the cover of the electrolytic cell. Connection is made to the inner ends of the platinum pins by copper or other wire, the tube then being filled with pitch, etc. Instead of the net-work of platinum wire, each glass tube may support a long piece of platinum wire folded into a plurality of loops. Instead of glass tubes, vitrified porcelain may be used, which is said to be more durable in contact with chlorin than the glass.

667,421, February 5, 1901, Henry Blackman, of New York, N. Y.

Relates to means for making electrical connection with anodes or other electrodes, and consists in boring a hole in the top of the electrode down into its mass, as large in diameter as its thickness will permit. In the hole is inserted preferably a zinc rod having a spiral roll of hard rolled sheet zinc secured to it and wound tightly upon it. The rod and spiral roll are forced down into the hole, the spiral making good contact with the walls of the hole. Upon the rod and into the hole is forced a hard rubber tube, carrying upon its lower end a soft rubber ring, the soft rubber making a tight joint with the walls of the hole, the lower part of the hard rubber being beveled to make a tight joint with the upper edges of the hole. The hard rubber tube projects above the level of the electrolyte and is provided with a screw-threaded ring or cap which compresses a packing tightly against it and the conductor to prevent access of liquids to the interior of the tube.

667,498, February 5, 1901, William Thomas Chapman, of Manchester, England, assignor to the American Alkali Company, of Philadelphia, Pennsylvania.

Relates to means for vertically adjusting the height of electrodes in a cell, to allow for wear, breakage, etc. The upper end of the electrode has attached to it a threaded conductor rod by which it is supported from a threaded sleeve, which permits raising or lowering as may be desired.

673,453, May 7, 1901, Isaiah L. Roberts, of Brooklyn, New York, assignor to the Roberts Chemical Company, of New Jersey.

Relates to a connector for granulated carbon electrodes, such as are used in porous cups. The connector consists of a metallic plate embedded in a conducting cement, made of resin, asphaltum, and a conducting material, preferably carbon; between the cement and the granulated carbon electrode is a layer of powdered carbon such as coked anthracite coal, to improve the electrical contact. For large electrodes several contacts may be placed at different positions. The entire top is then covered with asphalt or similar seal.

689,877, December 31, 1901, Luke Hargreaves and William Stubbs, of Farnworth in Widnes, England.

Relates to anodes and provides means for protecting the metallic part thereof from corrosion by the electro-

lyte. Where blocks of carbon are secured to a vertical metallic conductor, the latter is encased in a tube of protecting material, the tube being filled with a suitable oil, such as a resin oil containing resin dissolved in it, the oil completely covering the metallic parts, and penetrating by capillarity the pores of the carbon. With electrodes suspended from a horizontal metallic conductor, they pass through a shallow tray containing the oil, the tray resting upon the cell.

715,684, December 9, 1902, Frank McDonald, of Johnsonburg, Pennsylvania.

Relates to anodes and consists of a plurality of strips of thin ribbon platinum-foil, which may be two inches wide in some cases and of suitable length, sealed into the end of a glass tube, containing mercury, into the upper end of which projects a conductor. The tube may be closed by a plug of cement forming an air-tight and liquid-tight joint.

(Complete prior to 1903.)

Notes

The Lack of Coke and Iron in Italy.—According to the Chamber of Commerce of the U. S. (Riggs Building, Washington, D. C.) the war has stopped in Italy entirely the arrival of foundry coke and low-grade pig iron from Germany, and the local Italian producers (Solvay Process Works at Vado and Savona near Genoa) are closed because they have no coal, and until the war is over very little coal and coke will come from England from which country Italy has been importing about 70,000 tons of coke per year. The imports from Germany, Austria and Belgium amounted to 220,000 tons of coke per year. The metallurgical or hard foundry coke which has come from Westphalia in the past was delivered in Milan at from $11 to $12 a ton, and at the present those who have any coke in stock are getting anywhere from $20 upward a ton. The unloading and putting on cars at Genoa and Savona is about 50 cents a ton, and the freight from these ports to Milan is just under $2 a ton. The port of Savona has special facilities for unloading coal and coke. There is a big demand for iron in Italy that compares in analysis with English hematite. American pig iron for malleable use, as well as the more ordinary quality, in the general foundry business, is also wanted. If the makers of pig iron care to investigate what appears to be an opening in Italy, the American Chamber of Commerce in Milan will be pleased to have them send over their analysis together with prices at the seaboard in America, as well as in Genoa. The hematite which sold before the war at about $21 delivered in Milan is not to be had now at less than $45 to $50, as the only iron ore available is Spanish hematite, of which the quantity is limited. The landing charges, freight and duty from steamer to delivery in Turin or Milan are about $4.50, of which $2 is freight, $2 duty and the rest handling and unloading.

The standard riffles on a Wilfley table vary progressively in length from 4 ft. 6 in. to 13 ft. 10 in. In depth they are tapered from ¼ in. to 1/16 in. in the shorter rifles, and from ⅜ in. to 1/16 in. in the long ones.

The price of tungsten concentrates in the Boulder county field, Colorado, has advanced to $10 per unit for 60 per cent WO_3, or $600 per ton. According to a consular report, the price for ferrotungsten in England has advanced to $1.34 per pound of tungsten contained in the alloy, and tungsten powder to $1.46 per pound.

The **Petroleum Industry of California** is the subject of a 600-page book, with a separate folio of maps, issued by the California State Mining Bureau, Ferry Building, San Francisco, Cal. The price is $2.

The study of sanitary conditions in and about mining and metallurgical plants has been undertaken by the Bureau of Mines. Some results of an investigation by Joseph H. White are embodied in *Bulletin* 87, entitled "Houses for Mining Towns." The bulletin contains illustrations and designs, showing good and bad conditions, and outlines the work done by large companies in laying out and maintaining mining settlements.

Book Reviews

Chemical Theory and Calculations. By **F. J. Wilson** and **I. M. Heilbron.** Price $1.00 net. New York City: D. Van Nostrand Company.

A first-class little book for beginners, if used under a good teacher. The explanations of fundamental chemical quantitative relations (such as of equivalent weights) are clear and convincing. The only drawback is that here and there a word is used loosely, or a necessary qualifying phrase omitted, which would need the attention of a sharp-eyed teacher to straighten out and thus prevent the student getting a fragmentary or faulty idea. The problem method is the only method to make absolutely certain that a student has mastered the fundamentals; for, if a student can work out a complicated problem correctly one may be sure that he is properly master of the principles involved.

Details of Cyanide Practice. By **Herbert A. Megraw.** Octavo (15 x 22 cm.), 215 pages, numerous flow sheets, drawings and illustrations; price $2 (8/4). New York and London: McGraw-Hill Book Company, Inc.

The work describes cyanide practice at fifteen important mills in North America, the facts being gathered from a tour which was intended to include Mexico, but this was prevented by the revolution in progress there. The chapters have already appeared as a series of descriptive articles in the *Engineering and Mining Journal.* The work presents the author's observations and personal opinions, and criticisms intended to promote discussion respecting details involving diverging practice.

Cyanide Practice, 1910 to 1913. Edited by **M. W. von Bernewitz.** Octavo (15 x 23 cm.), 732 pages, 133 illustrations. Price, $3. San Francisco: Mining and Scientific Press.

This a reprint of 205 articles which appeared in the *Mining and Scientific Press* from July, 1910 to January, 1913. It is a continuation of two similar compilations printed in 1907 and 1910. A great improvement over its predecessors is the classification of the articles under fifteen headings, conforming to the arrangement of the ordinary treatise on the cyanide process, instead of merely arranging them chronologically.

There is an immense amount of up-to-date information on the cyanide process in this book, written from many different standpoints and, therefore, of greater suggestiveness and value than if written by a single author. Incidentally, when one reflects that this mass of useful information was furnished by one single journal, from week to week, in timely installments, and that this is only one of several subjects covered by that journal, one obtains a vivid idea of the immense value given, at relatively small cost, by the columns of the active technical journals. This book is valuable in and of itself, but it proves the still greater value of the

periodical scientific press to the wide-awake technologist.

Methods in Metallurgical Analysis. By **Charles H. White.** Duodecimo (12 x 18½ cm.), 356 pages, 106 illustrations; price $2.50. New York: D. Van Nostrand Company.

The author is assistant professor of mining and metallurgy in Harvard University and the Massachusetts Institute of Technology. The book is intended for the use of students who have had adequate preparation in qualitative analysis and gives them the methods which have been most generally adopted in American metallurgical laboratories. The details are clearly stated in a manner indicating the author's long practice in teaching; the style is good, the methods well chosen, the printer's work first class. It is undoubtedly a very welcome book for the use of metallurgical students.

Metallurgy. By **Henry Wysor**. Second edition, revised and enlarged. 392 pages, 104 illus. Price, $3. Easton, Pa.: The Chemical Publishing Company.

A condensed treatise for the use of college students and the general reader. The bulk of it is good, though some parts less so; it is all necessarily brief. There is a very large amount of information in the book, of a kind adapted to give the reader a general idea of every phase of the subject. It is essentially a textbook, adapted for use as such by assigning lessons in it from cover to cover. For those who are so placed that they must teach metallurgy merely as a branch of industrial chemistry, this is probably as good a textbook as could be selected; but some omissions would need to be supplied and some errors corrected: *e.g.*, omission of petroleum among the fuels, explanation of *how* mercury ore is decomposed by heat, or the kind of electrodes in aluminium reduction pot. It is a book which might be satisfactorily used in giving an elementary course.

Steel Working and Tool Dressing. By **Warren S. Casterlin.** 12 mo., 207 pages. Price, $2. New York: M. T. Richardson Company.

The sub-title reads "A Manual of Practical Informationo for Blacksmiths and All Other Workers in Steel and Iron." The author is a practical blacksmith who has spent fifty-seven years at the anvil. He says in the preface: "I have worked in more different shops, done more traveling, and spent more time and money to perfect myself in the art of steel working than any other man on the continent." Again he says: "I shall never revise this book again. I have tried to do my duty. I have been cautious at every stroke of the pen."

It is difficult to criticise such an honest bit of writing. It is written in absolute sincerity, and it contains the quintessence of the experience and beliefs of the old, old school. Peace be to their ashes! No one can read it without learning some items of practical information; yet it is the duty of the reviewer to caution readers against the limitations of the author and the many errors in the book. The uninstructed would learn from it much that is questionable and some things that are wrong; they had better, therefore, leave it alone until they know more about steel from more reliable sources. Those initiated in steel will find it an interesting human document, and may find in it some crumbs of useful information.

Heat-Treatment of Steel. Collected from articles in *Machinery*. Octavo, 278 pages, illustrated; price $2.50. New York: The Industrial Press. London: The Machinery Publishing Co., Ltd.

This book is mainly compiled from articles published in *Machinery*, with amplifications and additions. It contains a large amount of information and some misinformation, thrown together in a miscellaneous receipt-book sort of way. At places it is quite good, but at others it is pretty poor. A reader well acquainted with the subject might glean some useful information by reading it through critically; one unacquainted with the subject will run the risk of learning it in a disjointed, unsystematic manner which will give him but little real mastery over it. It may be possible that mechanics need to have an art presented to them in this sketchy, jumbled sort of way in order to read it understandingly, but we doubt it.

The Sampling and Assay of the Precious Metals: Comprising Gold, Silver, Platinum, and the Platinum Group Metals in Ores, Bullion, and Products. By **Ernest A. Smith.** Octavo (15 by 22 cm), xv + 460 pages, 166 illustrations; price, $4.50 net.

The author is connected with the Sheffield Assay Office, but was formerly teaching the subject at the Royal School of Mines, London; he dedicated the work to his father, Richard Smith, one of the original staff of the Royal School of Mines, on its formation in 1851.

The author's aim has been to make the book exhaustive and comprehensive. Particular attention is given to sampling. We would describe the treatment as being less scientific than Fulton's "Manual of Fire Assaying," and therefore less instructive to the student. A curious misnomer exists in the title: assay is "*for*" the precious metals, not "*of*" them.

Blowpipe assaying for gold and silver is acknowledged to be useful, particularly to the prospector, and therefore deserved a chapter instead of three-fourths of a page. The miscroscopic measurement of small assay buttons from small amounts of ore or from very lean ores, is not mentioned; also, methods particularly adapted to assaying country rock or sea-water are not given, yet should be considered in a comprehensive treatise.

It is a fine book, but could be improved in a few respects.

Gemeinfassliche Darstellung des Eisenhüttenwesens. Compiled and published by the Verein deutscher Eisenhüttenleute. Ninth edition, octavo xii + 438 pages, 68 illustrations, many diagrams; price, bound in cloth, 5 marks (retail in New York $1.65). Düsseldorf: Verlag Stahleisen.

A well-written, beautifully printed and illustrated exposition of the present methods of manufacturing iron and steel. The space given to each topic is necessarily brief, but it is utilized most skillfully. To those reading German easily it gives a very readable and instructive picture of the iron industry. Over one-third of the book is devoted to statistics of the iron industry in all parts of the world and nearly one-fifth to an exhaustive list of all the firms making and working upon iron and steel in Germany.

Einführung in die Metallographie und Wärme Behandlung. Von H. Hanemann. 16 x 24 cm., 128 pages, 25 diagrams in the text, 110 photomicrographs on plate paper. Price 10 marks (retail price in New York $3.35). Berlin: Gebrüder Borntraeger.

The author is director of the metallograph division of the iron and steel laboratory at the Technical High School in Berlin. This book embodies twelve lectures given by him to metallurgical, chemical and mechanical engineers in a summer school course. It is, therefore, not a comprehensive text-book, but merely a clear-cut statement of the best of present methods and results in the microscopic study of metals and their improvement by heat treatment. It is clearly written, and the photographs are excellent and most instructive.